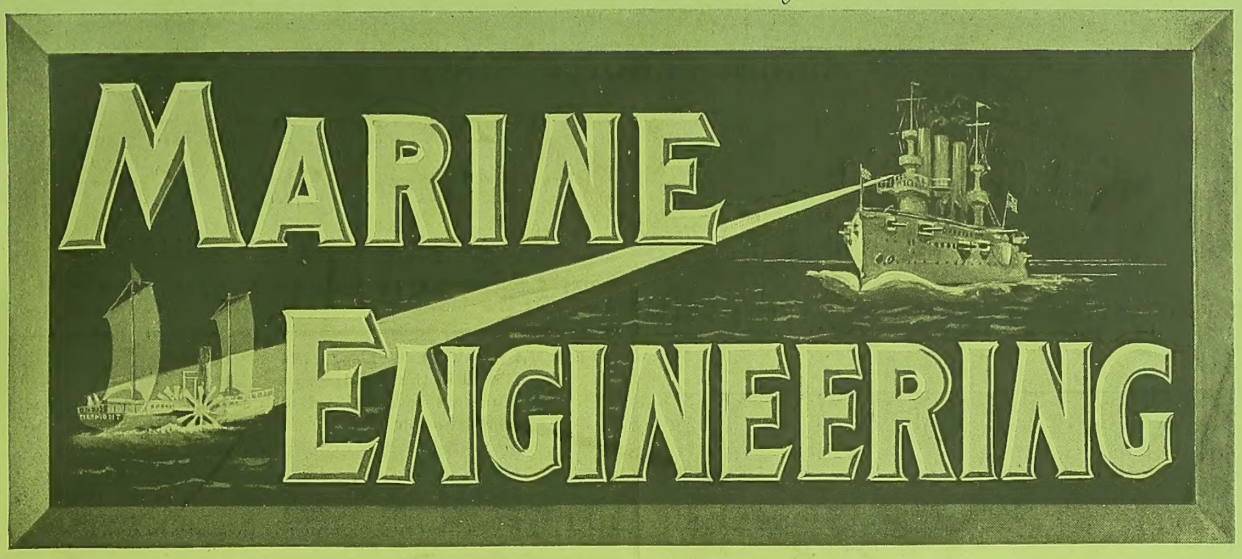

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MARINE ENGINEERING.

Vol. 3. NEW YORK, JANUARY, 1899. No. 1

PARSONS' EXPERIMENTAL BOAT TURBINIA WITH RECORD OF 32.75 KNOTS.

Our illustration shows the fastest boat in European waters—the Parsons experimental boat Turbinia—exhibiting her paces to a number of experts, who were stationed on the boat from which the photograph here reproduced was taken. The boat was running at her maximum speed, and though the photograph was of necessity made with the briefest exposure the details are wonderfully distinct. Our regular readers will recollect the description of this boat published in previous issues. She is 100 ft. long, 9 ft. beam and displaces 44 1-2 tons, and the "go-ahead" turbines develop 2,100 I. H. P. Many exaggerated statements regarding the speed of this boat have appeared in print, but the official speed, and that claimed by the inventor, the Hon. Charles Algernon Parsons, is 32.75 knots. The Parsons Marine Steam Turbine Co. has now a large works at Wallsend-on-Tyne, England, and has already booked orders for destroyers of the highest speed.

PARSONS' 100-FT. EXPERIMENTAL BOAT TURBINIA STEAMING "FULL SPEED AHEAD."
(Photo. by West, Southsea.)

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FRAGMENTARY REMARKS ON THE WATER-TUBE BOILER IN MARINE WORK.

BY WILLIAM BURLINGHAM.

In full-powered vessels the use of the water-tube boiler in this country has been extremely limited. There are many builders of water-tube boilers here, and in yachts, river craft and small vessels of various types, their boilers, chiefly of the small tube variety, have been extensively installed. Many manufacturers make excessive claims which are not made good in practical every day use; and faulty design, and the inexperience and prejudice of engineers and firemen have contributed greatly to the slowness with which the water-tube boiler has been taken up. This type of steam generator has suffered from the disadvantage also, from its birth, of direct comparison with the Scotch boiler, which in its present form is the result of slow evolution from crude beginnings.

Three examples of the largest water-tube boiler installations in this country are those of the steamships Northwest and Northland on the Great Lakes and the La Grande Duchesse on the Atlantic coast. The two first named are fitted with Belleville boilers and the latter was fitted with Babcock and Wilcox boilers. Considerable difficulty was experienced in the working of the boilers of the Northwest and Northland, and in the case of the La Grande Duchesse her water-tube boilers were removed after about a year's trial and replaced with Scotch boilers fitted with Ellis & Eaves induced draft.

To get the utmost efficiency from a water-tube boiler installation the entire machinery outfit must be designed for a high pressure. To use an engine, for example, that could be as readily furnished with steam by a Scotch boiler means that one-half of the plant is so heavy that little is gained in the direction of saving of weight, and one of the greatest advantages to be derived from the use of the water-tube boiler is thus neutralized. A type of engine following the designs now universally used in naval vessels appears to be the most suitable. Two principal sources of trouble, so far as the main engines are concerned, accompany the use of high pressure steam. They are: first, the actual increased pressures, and, second, the greater temperatures occasioned. As to the first, we are not yet near the point where the resulting stresses are too great for the present materials of construction, and so we can provide by suitable design for all the effects which result from the statical pressure of the steam.

The second source of trouble, temperature, is lessened by the fact that its rate of increase is rapidly diminished as the pressure is increased, as for instance the same increment of temperature, 38.1 degrees, that causes the pressure to rise from 90 lbs. to 150 lbs. is sufficient to cause an increase of pressure from 210 to 320 lbs., and we have several steamers working satisfactorily at 200 lbs.

Superior design has provided for efficient pipe joints and gland packings. The pipe joints of the British cruisers Powerful and Terrible have proven excellent, and are made by the insertion of a ring of copper wire between the two steel or composition flanges, the setting up of the bolts, slightly flattening this wire, produces a permanent joint. This joint is also used for the bottom of the cylinder liners.

The Engineer-in-Chief of the British Navy has made a series of careful experiments as regards the strength of various materials and alloy when subject to high temperatures; in many cases 1,300 deg. Fah. was reached. The general results are summed up thus:

The ultimate strength of gun metal, copper, naval brass and manganese bronze is reduced; for mild steel, it may safely be assumed that up to 800 deg. Fah. there is no loss of strength. At a temperature of 400 deg. the loss, in Government composition (88 copper, 10 tin, 2 zinc) is from 10 to 15 per cent. Lead will make such alloys very unreliable. At the same temperature the losses sustained by other metals are: Naval brass, 5 per cent; manganese bronze, 8 per cent; copper (ordinary), 7 per cent; copper (compressed), 11 per cent. For mild steel, some Portsmouth experiments gave 7 per cent. At 400 deg. the principal loss is sustained by composition, but the reduction does not exceed 2 tons out of an original 14 tons.

Under normal conditions, the temperature of the machinery and boilers will not exceed the temperature of the steam in the water-tube boiler, and as this is raised but 35 deg. or so, in going from 200 to 300 lbs. pressure, we need have no feeling of doubt as to the strength of our materials.

The two principal reasons for the use of the water-tube boiler in the merchanat marine are: first, the immense saving in weight, and, second, the increase in economy by the use of high pressure steam.

As to the question of economy, probably the experiments of the British Admiralty committee are the most exhaustive, embodying, as they do, the results of over 500 trials of ninety-five ships. The trials were all over twelve hours' duration, under ordinary service conditions, in all parts of the world and with coal of ordinary quality. These trials have shown that about 90 per cent of the theoretical gain due to the use of increased pressures has been realized in practice, and we are, thereby, safe in assuming that an increased gain will be realized at the higher pressures of water-tube boilers. Briefly, 8 per cent was gained by the use of steam of 150 lbs. pressure, and a gain of 12 1-2 per cent is expected from a pressure of 250 lbs.

Although in many ways defective, the water-tube boiler as it now exists is steadily coming into favor, and will no doubt in time supplant the Scotch type for all services. The new battleships and monitors for the Navy will probably be equipped with water-tube boilers of the large tube type. Already the small tube type of boiler has been extensively used in torpedo vessels here. The Thornycroft has been the favorite type with our builders for this work and a brief sketch of the changes that have taken place in its design during the past few years may be of interest. This type will probably be used on the majority of the torpedo boats and destroyers building under the last Congressional appropriation.

Fig. 1 shows the original commercial type of the

Thornycroft boiler as used in the British torpedo boat Speedy and her class. This is also used on the United States boats Cushing, Ericsson, Davis, Fox, Mackenzie and McKee.

In 1893 it was fitted on the Speedy and from her trials the I. H. P. per ton of boilers and water was found to be 52.8. Since 1894 she has been employed in actual service with the Channel Squadron and excellent reports have been received of her behavior, although the tubes are gradually corroding and will have a life of about 4 1-2 to 5 years. This is less than we credit tubes with, but in the face of the British experience it is not safe to assume that they will last longer.

These boilers cannot be worked at a high rate of power with much salt in the feed water, a feature common to all small tube water-tube boilers, and special care is therefore necessary that all the joints of the feed water system exposed to salt water are well packed.

The chief objections to the "Speedy" type of boiler consisted in the length necessary to allow for the return of the downcast pipes, the small height of the furnace, and the inaccessibility of the tubes. Subsequently a new model was constructed for the "Daring" type of British destroyer and took its name from that boat.

These were of less weight comparatively, had greatly improved furnaces, and the tubes were much more accessible. The grate area, considering the available space and the heating surface, was increased enormously. Fig. 2 shows the type which is also used in the U. S. destroyers Farragut, Stringham, and Goldsborough.

An improved "Daring" type now called for on our latest torpedo boats is shown in Fig. 3. In this type the side water drums are made 18 in. dia. instead of 7 1-2 in. as in the original "Daring" class. This is supposed to allow of easier access for expanding and plugging the tubes. It is an open question, however, whether this compensates for the loss of grate area in the boiler. As a special tube expander must be used in either case, an 18 in. hole being too small for a man to do any work, it would seem better to invent a tube expander and plugger that would do the work perfectly than to lose this valuable grate area.

FIG. 1.—"SPEEDY" TYPE.

After the Thornycroft, the boiler of the small tube type with which the British have had the most extensive experience is the Normand, controlled in Great Britain by Laird Bros. and J. & G. Thompson. This type has given satisfaction in all cases where

DIMENSIONS, ETC., THORNYCROFT "SPEEDY" BOILERS.

Total I H.P.	Dimensions Over Casings.			Tube Surface, Square Feet.	Grate Area, Square Feet.	Weight with Water to Working Level, Tons.	Air Pressure in Stoke Hold.	Steam Pressure on Trial.
	Length.	Height.	Width.					
39	37 in.	31½ in.	48 in.	139	3.3	0.7	Chimney blast	145
46.7	54¾ in.	62 in.	55 in.	460	6.0	2.21	0.38	130
58	60⅛ in.	96 in.	70½ in.	586	12.0	3.78	Chimney blast	...
189	68 in.	72 in.	57 in.	774	8.5	4.3	2.16	145
194	69 in.	73 in.	56 in.	777	8.5	3.28	3.10	150
250	61 in.	80¼ in.	77½ in.	776	11.4	4.3	2.33	140
300	74 in.	90¾ in.	87 in.	1066	18.0	6.0	....	...
384	65 in.	79 in.	80 in.	937	13.0	4.53	3.41	250
400	82 in.	81 in.	66 in.	930	16.0	3.0	2.5	150
450	95 in.	98½ in.	8 ft. 10½ in.	1640	32.0	8.0	....	...
588	8 ft. 8 in.	9 ft. 3 in.	8 ft. 0 in.	2144	25.5	11.22	1.7	194
650	7 ft. 5 in.	8 ft. 11 in.	9 ft. 7 in.	2175	30.0	9.805	1.6	...
825	8 ft. 2 in.	9 ft. 0 in.	9 ft. 6 in.	2418	37.75	11.01	4.0	149
850	9 ft. 0 in.	8 ft. 9 in.	9 ft. 9 in.	2360	39.0	13.75	2.5	250
930	8 ft. 2 in.	9 ft. 1 in.	9 ft. 4 in.	2398	37.75	11.665	2.37	217
1242	8 ft. 2 in.	9 ft. 6 in.	9 ft. 0 in.	2583	36.8	13.565	2.5	205
1496	9 ft. 6¼ in.	10 ft. 2½ in.	13 ft. 3 in.	3095	63.0	15.66	2.75	209
1548	10 ft. 6 in.	10 ft. 6 in.	13 ft. 0 in.	2964	63.0	16.79	3.15	204
1867	11 ft. 6¾ in.	10 ft. 8⅛ in.	12 ft. 11⅞ in.	4020	65.3	18.63	3.5	211

FIG. 3.—IMPROVED "DARING" TYPE.

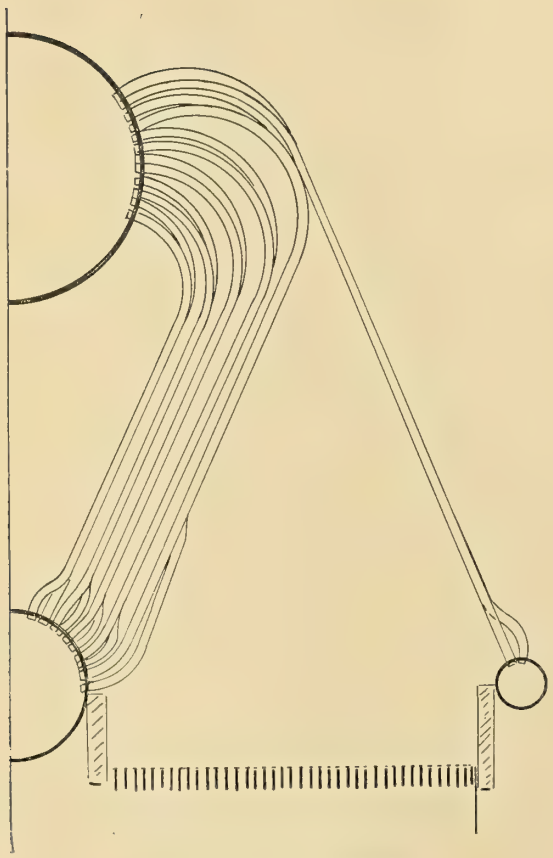


FIG. 2.—"DARING" TYPE.

steel tubes have been used, and is shown in Fig. 4. In the U. S. Navy the torpedo boats Porter, Dupont, Dahlgren, T. A. M. Craven, Morris and Gwin are fitted with these boilers.

Of the American small tube boilers, the Mosher is used in the torpedo boats Foote, Rogers, Winslow and Rowan, and the Seabury in the destroyer Bailey. The Ward type of boiler is used on the monitor Monterey, and in practically all the steam launches of our Navy.

A word or two as to the material of the tubes: In the English boat Lynx, fitted with four Normand boilers, a defective steel tube split, and the feed pump being common to two boilers, the effort of the water tender to keep up the water level of the split tube boiler, gave it all the water, the feed valves being wide open and the pressure low; consequently the water became so low in the other boiler that the tubes were overheated, reaching about 700 deg. Fah. The split tube boiler was then shut off and the water pumped into the overheated boiler; the upper part of this boiler then leaked considerably, but the tubes were little distorted, and the only repairs necessary were re-expanding throughout the upper joints of the tubes.

A more recent case occurred on the British boat Hardy, fitted with a Thornycroft boiler. The water in this boiler being allowed to get very low, caused overheating of the tubes, eventually blowing one out of the steam drum. After plugging up this particular tube, the boiler needed no further repairs, the distortion of the tubes being insignificant. From an examination of these tubes the water level was shown to have fallen to such an extent that if it had occurred in an ordinary Scotch boiler it would have assuredly caused the dropping of the crownsheets and furnaces.

In many of the original British destroyers the boiler tubes were of copper. The great trouble with these was that they would split or bend and the tubes near the fire would warp out of shape. Examination showed the burned and deteriorated character of the metal and its unsuitability for such conditions. As the split tubes were found to be next the fire, four rows of solid drawn steel tubes were substituted, and on service this worked all right for a time, but when the copper tubes became dirty, more or less trouble was experienced with them, and eventually all the tubes were made of solid drawn steel. Our own gunboat the Nashville has copper tubes in Yarrow boilers, and these are giving the same trouble that the English experienced; they will shortly be taken out and solid drawn steel tubes substituted.

Two or three cases of splitting have occurred with these steel tubes, but all have been traced to original defects of the material.

The tests of the Admiralty as given by Mr. Oram, Senior Engineering Inspector of the British Navy, are as follows: Each tube is tested to 1,500 lbs. per sq. in. by water pressure, and various expanding and flattening tests are applied to a certain percentage of them, to show their ductility and other working qualities.

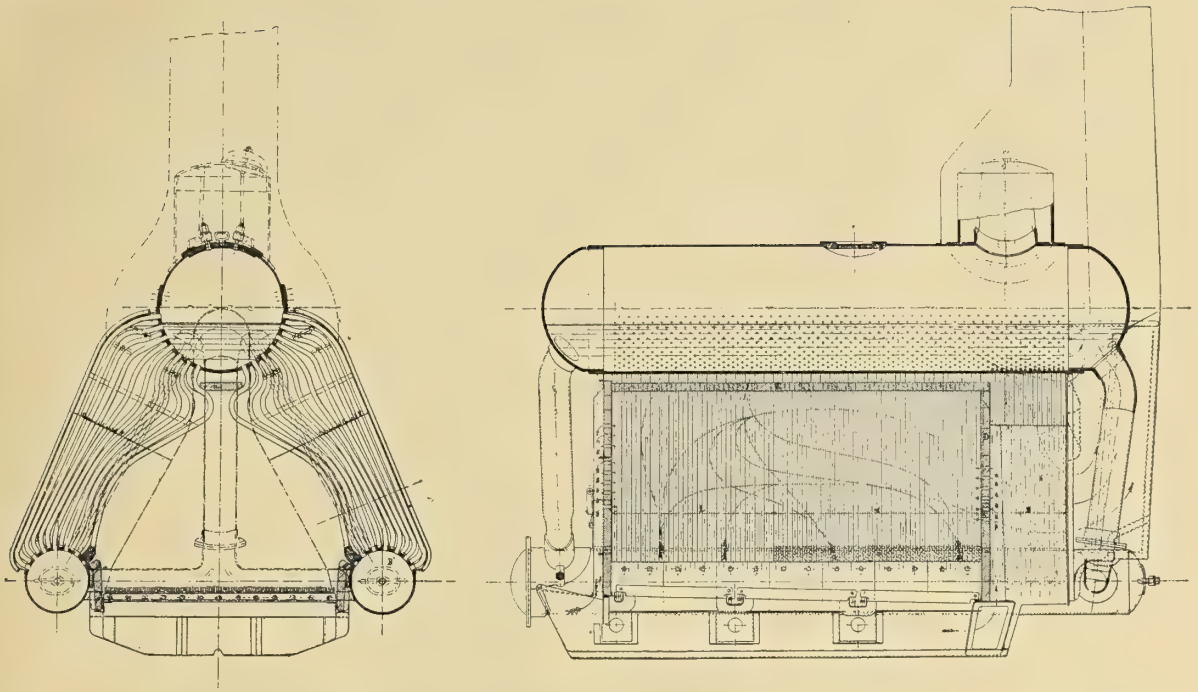


FIG. 4.—NORMAND WATER-TUBE BOILER.

The United States Navy specifications for tubes are very similar. The tubes are first inspected for surface defects, etc., tested for gauge and then from every lot of 100, four tubes are taken at random, and subjected to the following tests:

(1) The open end of one tube, after annealing, is flattened by hammering until the sides are parallel, the inside radius of the corners of the tube being equal to twice its thickness.

(2) A piece, one inch long, after annealing must stand crushing, in the direction of its axis, under a hammer, until shortened to 1-2 in.

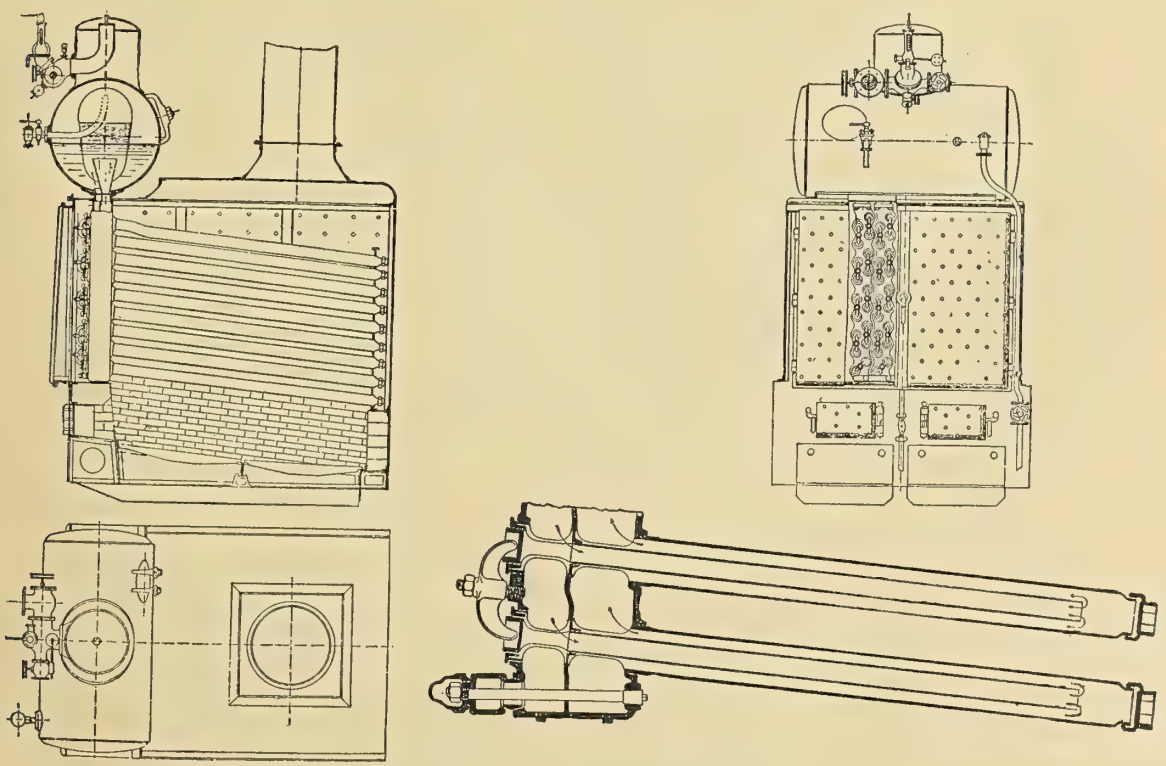


FIG. 5.—NICLAUSSE WATER-TUBE BOILER.

(3) The open end of one piece, cold after annealing, shall have a smooth taper pin, taper 1-2 in. to the foot, driven into it, until the end of the piece stretches to 1 1-8 times the original diameter.

(4) The open end of one piece, heated to a bright cherry red in daylight, shall have a smooth taper pin, 1 1-2 in. taper to the foot, heated to a dull red heat in daylight, driven into it, until it stretches to 1 1-8 times its original diameter.

Each tube will be accepted, up to 8 per cent above the standard weight for the gauge ordered. Each tube must be subjected to 1,000 lbs. internal hydrostatic pressure.

These tests must be passed by the tubes without showing cracks, flaws or weakness.

It is the English practice, to galvanize all tubes externally, with a view of preventing external corrosion, and this process brings out defects that are not revealed in ordinary examination. The tubes are first pickled in weak acid, removing all scale, then a coating of 1 1-2 oz. of zinc per square foot is added.

Experiments of the English Admiralty, as given by Mr. Oram, regarding the steam pressure necessary to burst sound tubes, are of interest in this connection.

A copper boiler tube, 1 in. external diameter and .07 in. thick, was partly filled with water, the ends closed and the tube inclined at an angle of 20 degs. to the horizontal. On being heated by a blast, the pressure rapidly rose to about 2,000 lbs., the tube bursting 6 1-2 minutes after the pressure first appeared on the gauge. The entire portion that had been subjected to the heat was found to have been split open and practically flattened. This pressure would correspond to a stress of about 6 1-2 tons per sq. in. and a temperature of steam of about 640 degs.

A similar experiment was made with a new steel tube, 1 1-4 in. dia. and .104 in. thick, which had been formed into a spiral 6 in. dia. This tube was one-half filled with water and burst at 4,788 pounds per sq. in. It was flattened out locally, but not nearly so extensively as in the case of the first one. The stress per square inch was about 12 3-4 tons, and the steam temperature 800 degs.

The experiments show that sound tubes require a considerable pressure to burst them, and while steel tubes do not suffer materially, there is no doubt but that copper tubes get sufficiently hot to lose their strength.

Of the large tube type of water tube boiler there is but little data in this country to guide us in the choice of a suitable type.

DIMENSIONS, ETC., NORMAND WATER-TUBE BOILERS.

	Long and Low Type	Short and High Type	Long and Low Type	Short and High Type
Length over all	13 ft. 1 in.	11 ft. 8 in.	13 ft. 3 in.	11 ft. 6 in.
Height over all	10 ft. 6 in.	11 ft. 10 in.	11 ft. 3 in.	12 ft. 8 in.
Width over all	9 ft. 6 in.	9 ft. 5 in.	11 ft. 2 in.	11 ft. 0 in.
Tubular heating surface	1,830 sq. ft.	1,830 sq. ft.	2,360 sq. ft.	2,360 sq. ft.
Grate surface	38 sq. ft.	38 sq. ft.	45 sq. ft.	45 sq. ft.
Pressure	200 lbs.	200 lbs.	200 lbs.	200 lbs.
Approximate weight without water for light steamers, torpedo boats, etc	23,408 lbs.	22.960 lbs.	27,236 lbs.	26,900 lbs.
Ditto for larger steamers, cruisers, etc	25 5?0 lbs.	25.322 lbs.	29,934 lbs.	29,54- lbs.
Weight of water	5,892 lbs.	5.488 lbs.	6,832 lbs.	6,385 lbs.
Total weight in each case { light steamers	29.300 lbs.	28,448 lbs.	34.068 lbs.	33.285 lbs.
Total weight in each case { larger steamers	31.422 lbs.	30.810 lbs.	36.766 lbs.	35,933 lbs.

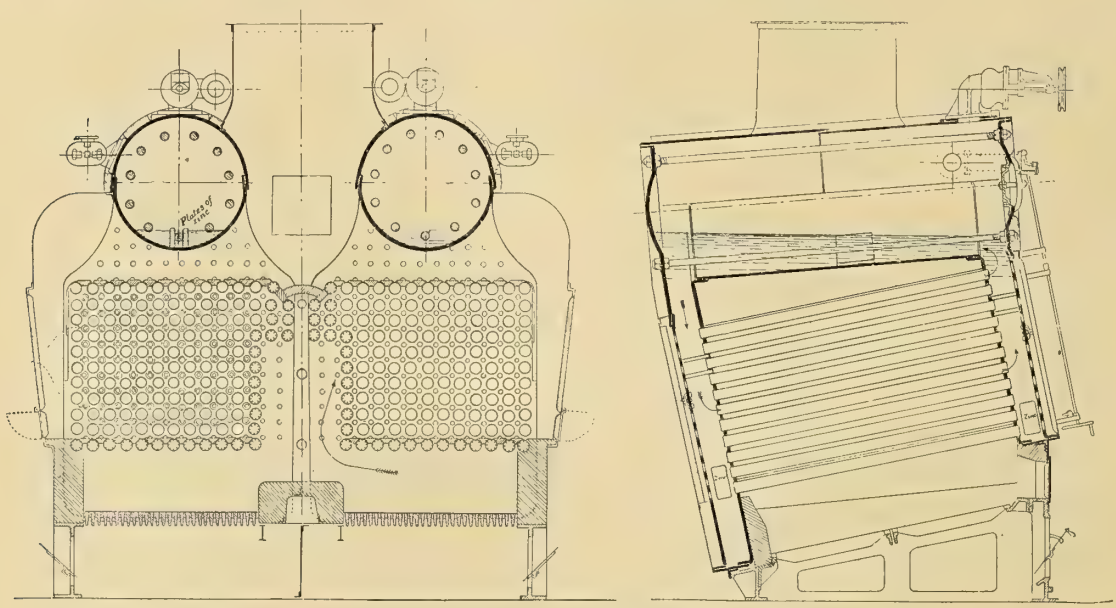


FIG. 6.—D'ALLEST WATER-TUBE BOILER.

This has given rise to a great variety of opinion about the merits of this type of boiler, with reference especially to the equipment of the new battleships and monitors.

The Belleville is the boiler that is extensively used in the British Navy, and is fitted in the cruisers Powerful and Terrible. A later type of the same boiler has been installed in the "Diadem" and the boats now under construction. The later type is the one fitted with the economizer above the usual elements thus forming a combustion chamber above the water tubes for thoroughly mixing the gases before they impinge on the tubes of the economizer. The Belleville boiler has been in use since 1886 in the Messageries Maritime, a prominent French line, and is apparently very satisfactory. A British officer was sent on a voyage in one of the company's boats to Australia and back, and his report was entirely favorable; so much so, in fact, that this, with the experience of Sir John Durston, was sufficient to insure their adoption in the British Navy. Our own reports of this type are not so favorable, and this, in conjunction with the fact that a number of auxiliaries have been found necessary for the successful working of this boiler, has delayed its adoption in this country.

It might be asked, had the Niclausse or Lagrafel D'Allest boilers been taken up by the British and nursed as carefully as the Belleville, would they not have given as good or better results? These boilers, in fact, will work without the assistance of any auxiliaries other than the usual feed pump.

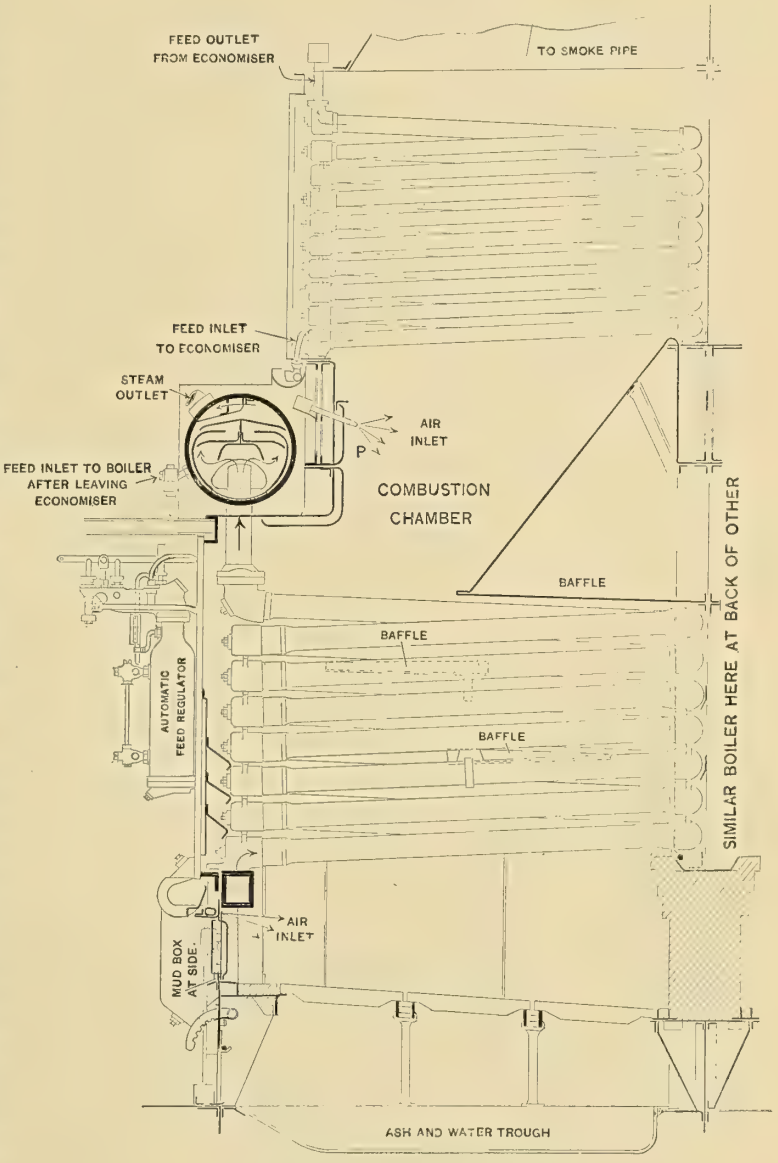
The Niclausse boiler, Fig. 5, is used more extensively in France than elsewhere, although Messrs. Humphreys, Tennant & Co. are installing a set in the British ship Seagull, and the Russians have several thousand horse power in use. The majority of the reports from the ships using them speak of the boiler as doing very satisfactorily. A well known American shipbuilder will probably use this type of boiler in one of the new battleships.

The Lagrafel D'Allest boiler, Fig. 6, is almost entirely limited to the French Navy, and is a good second to the Belleville, the D'Allest having over double the horse power in use that is credited to the Niclausse, a fact hardly realized in this country. A statement of the total horse power of these three boilers, as used in the navies of England, Russia and France, is shown in the next column.

These figures are practically correct and show the preponderance of the Belleville type. They represent merely the horse power of the battleships and cruisers, small vessels not having been taken into account.

Navy	Belleville	Niclausse	Lagrafel D'Allest
Russia.....	146,900	5,000	Unknown but small
England.....	182,000	3,500	Unknown but small
France	217,400	70,000	165,400

The Lagrafel D'Allest is probably the best of the attempts to secure a substitute for the Scotch boiler. This boiler is not quite so heavy as the Belleville, but the floor space occupied is greater for the same area of grate or heating surface; as, however, the D'Allest is much more capable of being forced than the Belleville, for the maximum power, the space occupied by the former is no greater than the latter. The cost of operating the D'Allest is less, and the amount of water it contains, although not so much as in the ordinary Scotch boiler, is yet enough to do away with



BELLEVILLE WATER-TUBE BOILER.

an automatic feed regulator and its necessary complications. The Belleville, however, has the advantage of freedom of the tubes for expansion, thus reducing the danger of leaks. The weight of the Niclausse and D'Allest is practically the same, for the same area of heating surface, but the Niclausse is not capable of the high forcing of the D'Allest. The lower rows of tubes in the Niclausse are more liable to burn out than those in the D'Allest, the peculiar construction of the former boiler precluding the use of Serve tubes. Both of these boilers give dry steam at high pressures, a point of advantage that is lacking in the Belleville. The economy of the D'Allest is better than either of the other two, and much nearer the Scotch boiler.

It seems extraordinary that we have no large-tube water tube boiler for marine use in this country that occupies the position in the eyes of the world that foreign (especially French) boilers do. There is a grand field open to the American who can furnish such a boiler, and there would seem thus to be a great opportunity for the competent engineeer to design a steam generator that would fill the present requirements. Of the small-tube variety there are many American boilers on the market which are probably as good as any of the foreign ones of their classes.

First Large Merchant Steamship Constructed in Japan—the Hitachi Maru.

The passenger steamship Hitachi Maru recently launched at the Mitsu Bishi Dockyard, Nagasaki, marks a distinct advance in Japanese shipbuilding. This vessel, which was built for the Nippon Yusen Kaisha (Japan Steamship Co.), is of the following dimensions: Length, 462 ft.; beam, 49 ft. 2 in.; depth, 33 ft. 6 in.; draught, 25 ft.; gross tonnage, 6,150 tons; displacement, 11,600 tons. She is built of steel, and is fitted with twin screws driven by triple-expansion engines of 3,500 horse power to give an estimated speed of 14 knots. Her classification at Lloyds is 100 A-1 (3 decks).

Previous to the construction of this vessel the largest vessels built in Japan were the Hashidate, a steel coast defense ship of 4,278 tons displacement and 5,400 I. H. P., carrying 30 guns of various calibers, with a speed of 17 1-2 knots, and the Akitsushima, a steel cruiser of 3,150 tons displacement and 8,516 I. H. P., carrying 19 guns. The Hashidate is a sister ship to two vessels built in France and the Hitachi is a sister ship to two for the same company built on the Clyde.

As might have been expected, such a notable advance was not achieved without encountering very great difficulties and incurring very considerable expense. In the first place, the greatest difficulty was found in assembling a sufficient staff of platers and riveters, who were recruited from almost every dockyard and boiler shop in the Kingdom, each gang being fully persuaded that its own peculiar methods were not only the best, but the only ones that could posssibly be adopted. The result was, of course, a large amount of wasted time, spoiled material, and defective work which had to be done over again. Miles of riveting had to be cut out and made good, and acres of defective plating replaced. In the first instance, Lloyds, acting on the report of two local surveyors, refused to rate her, and the Nippon Yusen Kaisha refused to accept her. Ultimately, after the whole of the defective work had been removed and replaced, they were requested to send over the best man they could possibly spare to make a fresh and independent survey. In the expert's report, addressed to Baron Iwasaki, president of the Mitsu Bishi Co., he said he found "the workmanship, including the riveting, satisfactory and equal in quality and efficiency to that done in good shipbuilding establishments in the United Kingdom."

LAUNCHING OF THE FIRST LARGE MERCHANT STEAMER CONSTRUCTED AT NAGASAKI, JAPAN.

Before undertaking the construction of the twin-screw vessel the Japanese company secured the

services of J. S. Clark, a naval architect, who was not only conversant with the best Scotch practice, but had also had considerable experience in surmounting the difficulties arising from half-trained labor and defective organization during some years professional engagement under the Spanish Government.

If the history of the new vessel from inception to launching could be written in full, it would afford a typical example of Japanese determination and independence. It would have been far cheaper and quicker to order the vessel complete and to enforce their authority and to insist that the rank and file should follow their directions implicitly; but they preferred to try their own experiments, and learn by experience cost what it might. Similar instances of this national trait may be continually observed. Foreigners in Japanese employment are becoming fewer in number each year, and the administrative powers intrusted to them are more and more curtailed.

The illustration herewith shows the Hitachi Maru just as she was taking the water, and incidentally gives a very fair idea of the picturesque harbor of Nagasaki.

The yard was laid out about 1860 by the Japanese Government under Dutch management, and was transferred to its present owners in 1884, since which time it has been rapidly extended. Iron shipbuilding was commenced in 1889. The concern now has two granite dry docks, respectively 523 ft. and 371 ft. long by 99 ft. and 66 ft. wide, with 27 ft. 6 in. and 24 ft. 6 in. over the sills at spring tide. There is also a patent slip with rails 750 ft. long and 30 ft. gauge and a lifting power of 1,200 tons, all of which are continuously occupied. The Hitachi Maru was launched without a hitch. The company employs about 3,500 hands and has taken another contract for a 6,000 ton vessel for the same owners. For these very interesting particulars and the engraving we are indebted to our contemporary the *Indian and Eastern Engineer* of Calcutta.

The Naval Board of Construction has recommended the sale of the old monitor Wyandotte. She is valued as worth about $7,000 as old iron. During the Spanish war she was in commission, manned by the Boston Naval Reserves.

The battleship Wisconsin was launched from the Union Iron Works, November 25. A delegation of visitors from Wisconsin was present and the vessel was christened by Miss Elizabeth Stephenson. This vessel is a sister ship to the Illinois and Alabama, both now under construction on the Atlantic coast. She is classed as a sea going coast line battleship, length, 368 ft. L. W. L.; extreme beam, 72 ft. 2 1-2 in.; mean draught, 23 ft. 6 in.; displacement, 11,525 tons. She will be propelled by twin screws, driven by vertical triple-expansion engines, and with 10,000 I. H. P. is expected to attain a speed of 16 knots. Her armament will include four 13-in. breech loading rifles; fourteen 6-in. rapid fire guns, and an extensive secondary battery, and also four long Whitehead torpedo tubes. The contract for her construction calls for her completion September 19, 1899.

DESCRIPTIONS OF THE STANDARD BOATS IN USE IN THE U. S. NAVY.*

BY ARTHUR B. CASSIDY, U.S.N.

The design of small boats for the Navy has been a problem which the naval constructors have been obliged to solve under circumstances somewhat similar to those affecting the designs of ships for the special purposes intended and under many conflicting and limiting conditions.

The necessities of special cases of boat design are illustrated by the dory of the New England fisherman, a light, handy craft of good freeboard and great carrying capacity. The average "banker" carries about a dozen dories, snugly nested by removal of the thwarts. Each boat is handled by two men and will carry in a draught of 12 ins. from 1,500 to 2,000 lbs.

The New Bedford whale-boat, famous for its speed, lightness and capacity, is an easy pulling boat with considerable sheer and sharp lines. The bow and stern are alike, so that the boat will work quickly in either direction, and there is considerable curvature in stem and stern post, so that it can be turned quickly by the boat steerer with his long steering oar and thus escape the fury of the whale. The boat is usually fitted with a small sail and center-board, carries a crew of seven or eight; five or six at the oars, a boat header and boat steerer, with all the necessary gear, harpoons, lances, tubs containing whale lines, etc. Each whaler usually carries about two spare boats, and in her complement of boats has more than enough capacity to easily carry all of the crew.

The surf boat is one with great sheer, full forward and after body, quick rise of keel forward and aft. A surf boat that has received great praise in the Navy is the Ranger boat, built at Mare Island, for use on the survey of the coast of Mexico and Central America.

The racing cutter or barge, built sharp and light as possible, is intended for racing in smooth water.

The light steam and naphtha launches, which are so popular along our coast in sheltered waters, are built as light as possible, and with their limited crew, serve their purpose admirably as pleasure craft in smooth water.

In each of the cases cited, the boat fulfils its purpose, but would be comparatively worthless if its use was attempted in any other class than that for which it was intended.

As in each of the above mentioned cases, so in the Navy, must the boats be designed for their specific purpose. They must be strong enough to stand rough usage in rough water. They must be stable under sail or oars, have great carrying capacity, and must be as light as is consistent with the necessary strength. The steam cutters must have the power and strength of construction to not only carry their own load of officers and men, ranging from sixty in the 40-ft. steam cutters to thirty-five in the 28-ft.,

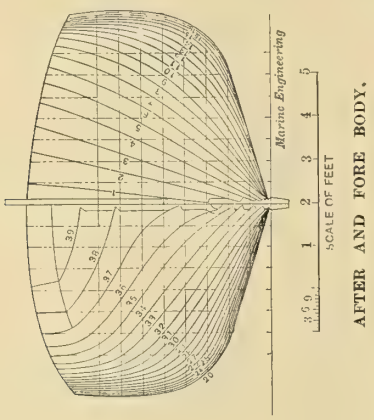
*A paper read at the Sixth General Meeting of the Society of Naval Architects and Marine Engineers, in New York.

but must be able to tow all the other boats of the vessel, loaded to their capacity.

As the usual space on naval vessels for the stowage of boats is limited, the number of boats that can be carried is also limited, so that in abandoning ship, when each man has his allotted place in a boat, there is not much spare room, as the boats, besides their human freight, must carry the requisite amount of provisions and water. Then, again, in landing parties, the men and equipments make a heavy load to carry, possibly through surf, to the shore, and with the banging upon the shore, require good, solid construction to stand the strain.

It is impossible to make the boats, in all their details, satisfactory to every one, but it is believed that the present types which have been adopted as the standard of the Navy more nearly fulfil all requirements and are more satisfactory to the majority of naval officers than any previous designs. These standard boats are not of an immediate growth, but are the result of experience of many years of actual service, and much time and thought by many men.

An order was issued by the Department April 1, 1870, relative to establishing uniformity in the size



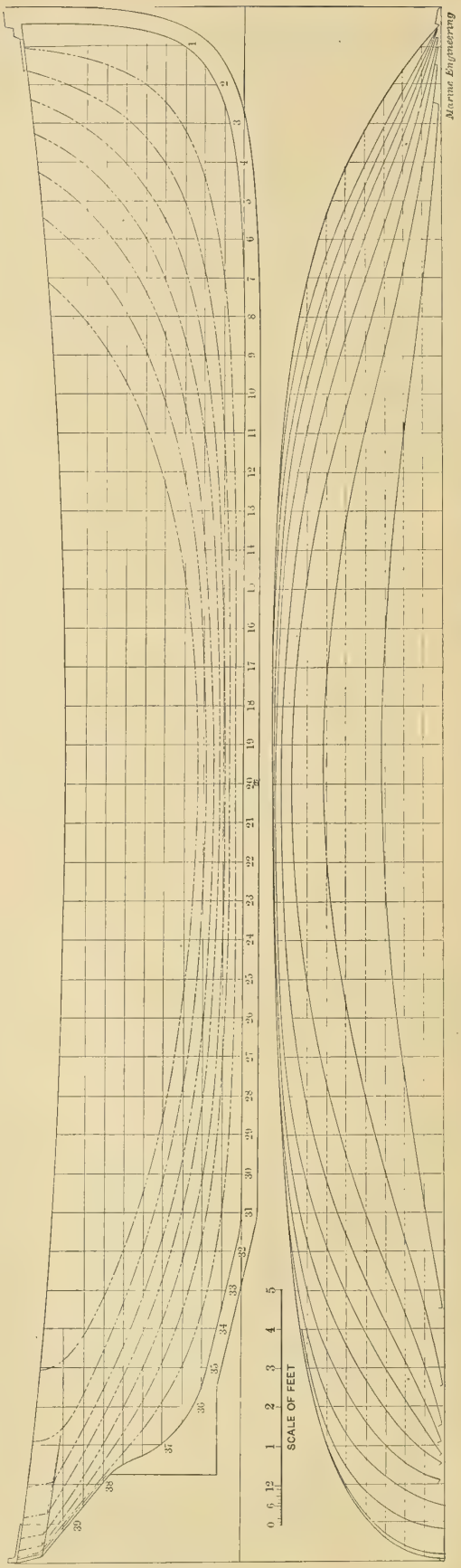
AFTER AND FORE BODY.

of boats. The vessels were classified, and a table prepared by John Lenthall, then Chief Constructor of the Navy, giving the size of boats that should be carried by each vessel, and also establishing the proportion of breadth and depth to the length, ranging from .282 of the length for breadth, and .4 of breadth for depth in launches, to .21 of the length for breadth and .39 of breadth for depth in whale boats.

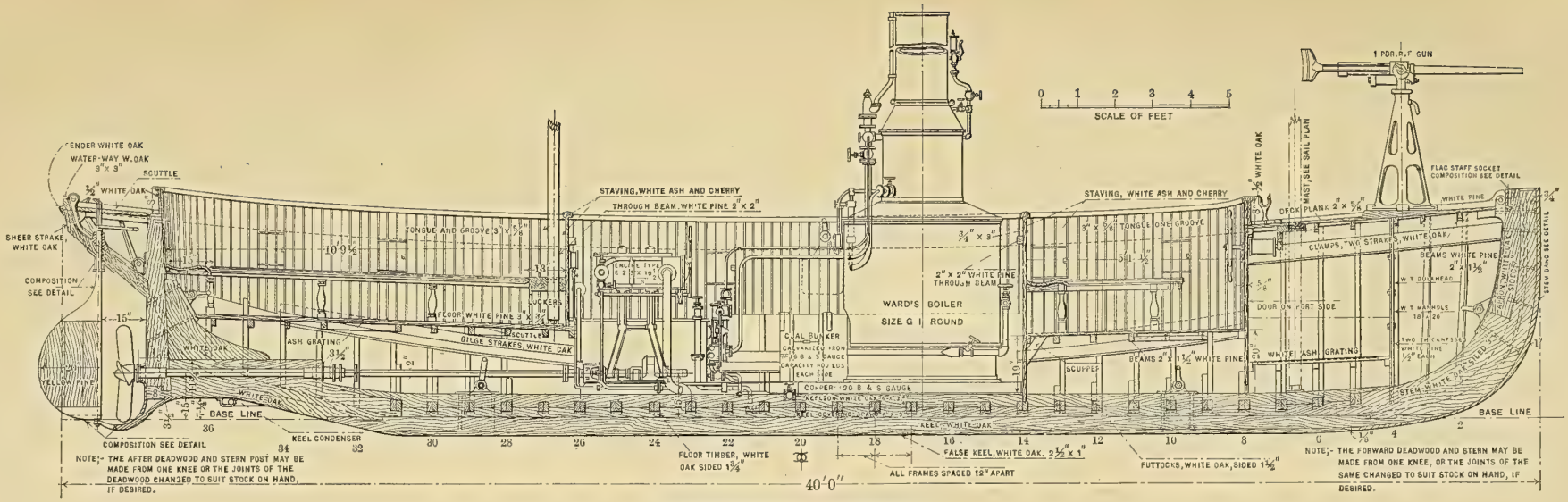
While this classified the boats as far as principal dimensions were concerned, there was no limit to the form of the boats, and in many cases the desire of the commanding officers, to have their boats faster than the boats of some other vessel, led to the construction of some tender boats entirely unfitted for naval use.

When it was determined by the present Chief Constructor to standardize the boats, the best boats in use were selected as the basis of the designs; the boats were studied for improvements, and the opinion of many officrs afloat was sought.

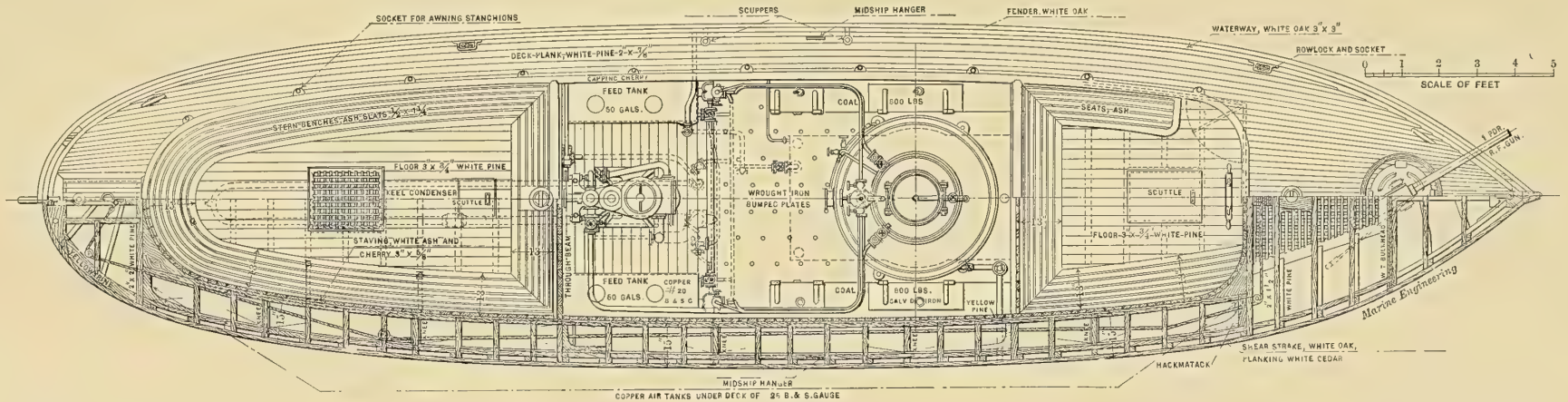
One point upon which all were united was, that the boats should have more carrying capacity. The principal difference of opinion was on the question of



LINES OF THE 40 FT. STANDARD STEAM CUTTER OF THE UNITED STATES NAVY.


1 PDR. P. F GUN
SCALE OF FEET
FENDER WHITE OAK
WATER-WAY W. OAK 3" x 3"
SCUTTLE
SHEER STRAKE WHITE OAK
COMPOSITION SEE DETAIL
STAVING, WHITE ASH AND CHERRY
THROUGH BEAM, WHITE PINE 2" x 2"
TONGUE AND GROOVE 3" x 1 5/8"
LOCKERS
FLOOR, WHITE PINE 3" x 3/4"
BILGE STRAKES, WHITE OAK
ASH GRATING
WHITE OAK
YELLOW PINE
BASE LINE
KEEL CONDENSER
ENGINE TYPE 6 2 x 10
2" x 2" WHITE PINE THROUGH BEAM
WARD'S BOILER SIZE G I ROUND
COAL BUNKER
COPPER 20 B & S GAUGE
KEEL, WHITE OAK
STAVING, WHITE ASH AND CHERRY
DECK PLANK 2" x 5/8"
DECK MAST, SEE SAIL PLAN
FLAG STAFF SOCKET COMPOSITION SEE DETAIL
CLAMPS, TWO STRAKES, WHITE OAK
BEAMS WHITE PINE 2" x 1 1/2"
DOOR ON PORT SIDE
WHITE ASH GRATING
STEM WHITE OAK SIDED
STEM BAND SEE DETAIL
FALSE KEEL, WHITE OAK, 2 1/2" x 1"
FUTTOCKS, WHITE OAK, SIDED 1 1/2"
FLOOR TIMBER, WHITE OAK SIDED 1 3/4"
ALL FRAMES SPACED 12" APART
40'0"
NOTE;- THE AFTER DEADWOOD AND STERN POST MAY BE MADE FROM ONE KNEE OR THE JOINTS OF THE DEADWOOD CHANGED TO SUIT STOCK ON HAND, IF DESIRED.
NOTE;- THE FORWARD DEADWOOD AND STERN MAY BE MADE FROM ONE KNEE, OR THE JOINTS OF THE SAME CHANGED TO SUIT STOCK ON HAND, IF DESIRED.

LONGITUDINAL SECTION.



DECK PLAN.

GENERAL ARRANGEMENT OF THE 40 FT. STANDARD STEAM CUTTER OF THE UNITED STATES NAVY.

rig; about 75 per cent. of the officers were in favor of the sliding gunter; the remainder in favor of the standing lug.

In the compilation of the standard designs, the classes were first determined. The classes and principal dimensions are shown in the accompanying table: (Table I, Page 12.)

The essential qualities of a design for naval boats would be classed as follows: 1st, safety; 2d, weight; 3d, comfort; 4th, speed.

In order to secure the first element, safety, the boat must be of such form as to give stability, both

under oars and sail. It must have strength to stand the strains of heavy weather, the rough usage which they sometimes receive when being hoisted and lowered, and must be able to stand considerable banging against the vessel, the wharf, or a float, and the shock of grounding on a beach, when landing with an expedition. The boats should have capacity

Principal Dimensions and Weight of Standard Boats of the United States Navy.

Type of Boat.	Principal Dimensions.			Weight.	
	Length extreme.	Breadth extreme.	Depth* from top of gunwale to lower edge of rabbet.	Hull.	Total, including outfit.
				Pounds.	
Steam cutters	40′-0″	9′-0″	4′-7⅞″	8064	18642
	36′-0″	8′-9″	4′-6″	7148	15719
	33′-0″	8′-7″	4′-5″	5120	12768
	30′-0″	8′-0″	4′-2″	4763	10631
	28′-0″	7′-8″	4′-0⅞″	3692	8889
Launches	33′-0″	9′-3″	3′ 8″	4359	6733
	30′-0″	8′-6″	3′-5″	2705	4769
	28′-0″	7′-5″	2′-8″	2150	3471
Cutters	30′-0″	8′-0″	2′-10″	2219	3384
	28′-0″	7′-5″	2′-8″	1872	2868
	26′-0″	6′-11″	2′-6″	1585	2460
	24′-0″	6′-6″	2′-6″	1100	1919
Barge	30′-0″	6′-11″	2′-8″	1712	2767
Whale-boats	30′-0″	6′-10″	2′-5″	1670	2537
	29′-0″	6′-8″	2′-5″	1463	2474
	28′-0″	6′-6″	2′-5″	1388	2344
	24′-0″	5′-11¼″	2′-2½″	1050	1781
Gig whale-boats	30′-0″	6′-2″	2′-5″	1375	2238
	28′-0″	6′-0″	2′-5″	1123	2014
Dinghies	20′-0″	5′-6″	2′-2″	700	1134
	18′-0″	5′-4″	2′-1″	516	950
	16′-0″	4′-6″	1′-10″	291	617
	14′-0″	4′-4″	1′-8″	236	537

*Note:—In case of Steam Cutters this heading should read—Depth from top of deck to lower edge of rabbet.

TABLE I.

to carry, in addition to their regular crew and stores, as large a number of men as possible, and they must have the form and a sufficient freeboard to be weatherly under sail in rough water, and to be able to carry as dry as possible her crew, the additional number of men allotted to the boat in abandoning ship, and provision and water for her complement.

Least Freeboard of Standard Boats of the United States Navy.

Type of Boat.	Maximum number of men boat will carry.	Weight of provisions and water.	Freeboard with maximum number of men and provisions.
Steam cutters 40′-0″	60	600 lbs.	1′-9½″
36′-0″	53	530 "	1′-9½″
33′-0″	48	480 "	1′-9½″
30′-0″	40	400 "	1′-8½″
28′-0″	35	350 "	1′-7⅞″
Launches 33′-0″	64	640 "	1′-10¼″
30′-0″	50	500 "	1′-9¼″
28′-0″	40	400 "	1′-1¼″
Cutters 30′-0″	45	450 "	1′-1″
28′-0″	40	400 "	1′-2½″
26′-0″	30	300 "	1′-0″
24′-0″	28	280 "	1′-0″
Barge 30′-0″	38	380 "	1′-0⅛″
Whale-boats 30′-0″	28	280 "	1′-1⅜″
29′-0″	25	250 "	1′-0⅜″
28′-0″	22	220 "	1′-1⅜″
24′-0″	18	180 "	—
Gig whale-boats 30′-0″	20	200 "	1′-2½″
28′-0″	16	160 "	1′-2½″
Dinghies 20′-0″	12	120 "	1′-2½″
18′-0″	10	100 "	1′-0½″

TABLE II.

The capacity in men, weight of provision and water, and the freeboard as shown in Table II.

As the boats must be strong, and scantlings made as light as possible, careful workmanship is insisted upon, in order that all the parts of the boat may be properly joined together.

While it is not intended to encourage extravagance, it is insisted that every appointment shall be strong, neat, and symmetrical without regard to expense.

The practice is to have all frames made of white oak, steamed and bent. In many cases where these frames have been made from flitches, or the natural crook, they have not stood the strain of a sudden shock, have broken from the blast of a gun, or the swinging of the boat against the vessel or wharf.

The keels, stem, stem-posts, keelsons, frames, risings, footlings, and wash strakes are built of white oak, the plank of white cedar, the thwarts of white ash, and the boats are copper-fastened throughout. The hanging bolts are of galvanized iron, and are strongly riveted over washers or plates in the stem, keel, or stern-post. All metal fittings of the boats are of brass.

A change has recently been made in the stern benches, slatted seats being used in place of the flat bench, thus giving an easy shaped seat, similar to park benches, upon which a person can more easily sit when the boat is in motion, and also insure a comparatively dry seat at all times; it is also intended to replace the cumbersome cushions.

The barges and gigs are always finished in mahogany, the back-board being curved and carved with an appropriate design.

The whale-boats and gig whale-boats are fitted with copper tanks under the bow and stern sheets, and at the sides under the thwarts, to make them better life-boats.

The 30-ft. whale-boat has a tank capacity of 14 cu. ft. The steam cutters are also fitted with copper tanks; the 40-ft. steam cutter has, including a water-tight compartment at the bow, 62.3 cu. ft.

Of the fittings of the boats, the greatest difficulty has been with the detaching apparatus of life-boats. Many kinds have been used, and failures to work at the proper time have been noted. The automatic releasing hook is now being largely used in the Navy. By this appliance, the boat is under control from the deck, and is rapidly lowered, and automatically released as soon as the boat touches the water.

The second element of the designs is that ever present question demanding the constant attention of the naval architect—weight.

As previously stated, the scantling is reduced as much as is consistent with the necessary strength. The designs have been studied from three points of view—safety, strength and weight, and wherever it seemed possible to cut the weight, it was done.

In the systematic arrangement of the thwarts, the bow oarsman is located far enough aft not to be cramped in his movements, and also to give a large fore sheet for all necessary purposes.

The bows have a considerable flare to make them dry, and the lines are made as sharp as possible, keeping in view the capacity required.

Under the third element of the boat designs—comfort—might be specified the slatted seats in the stern sheets of all boats except launches and dinghies. It has been the aim in the standard designs to give the crew of the boat ample room for pulling, and the thwarts have been arranged both vertically and horizontally to that end.

The element last to be considered in the Navy boats

is speed, and as the speed of a steam cutter is closely associated with the space and weight, any attempt at anything but moderate speed could not be considered in a Navy boat.

In rough waters, where the usual service of the boats would be performed, the speed ranges from 8 knots in the 40-ft. steam cutters to 6 knots in the 28-ft. cutters.

Many of the crews of the old Navy took a great deal of pride in their racing cutter, but in the new Navy, where everything has to be well considered from many points of view, the racing cutter seems out of place. As the boats are standardized, and those of all vessels are alike, size for size, a boat race would become a question of strength and endurance, and be much more interesting than a race between two boats of unequal form.

Under sail, the boats will not be speedy, as the sail power has been purposely kept low to keep down the size of spars, and the weight of sails and spars.

In the steam cutters, the sail area is 1.75 times the area of the load water line; in the launches, 3 times; in the cutters, whale-boats, and gig whale-boats, 2 1-2 times; and in the dinghies, 2 1-4 times.

The sail area of each boat is given in Table III printed on this page.

The life of the Navy boats is comparatively short, probably averaging 10 years.

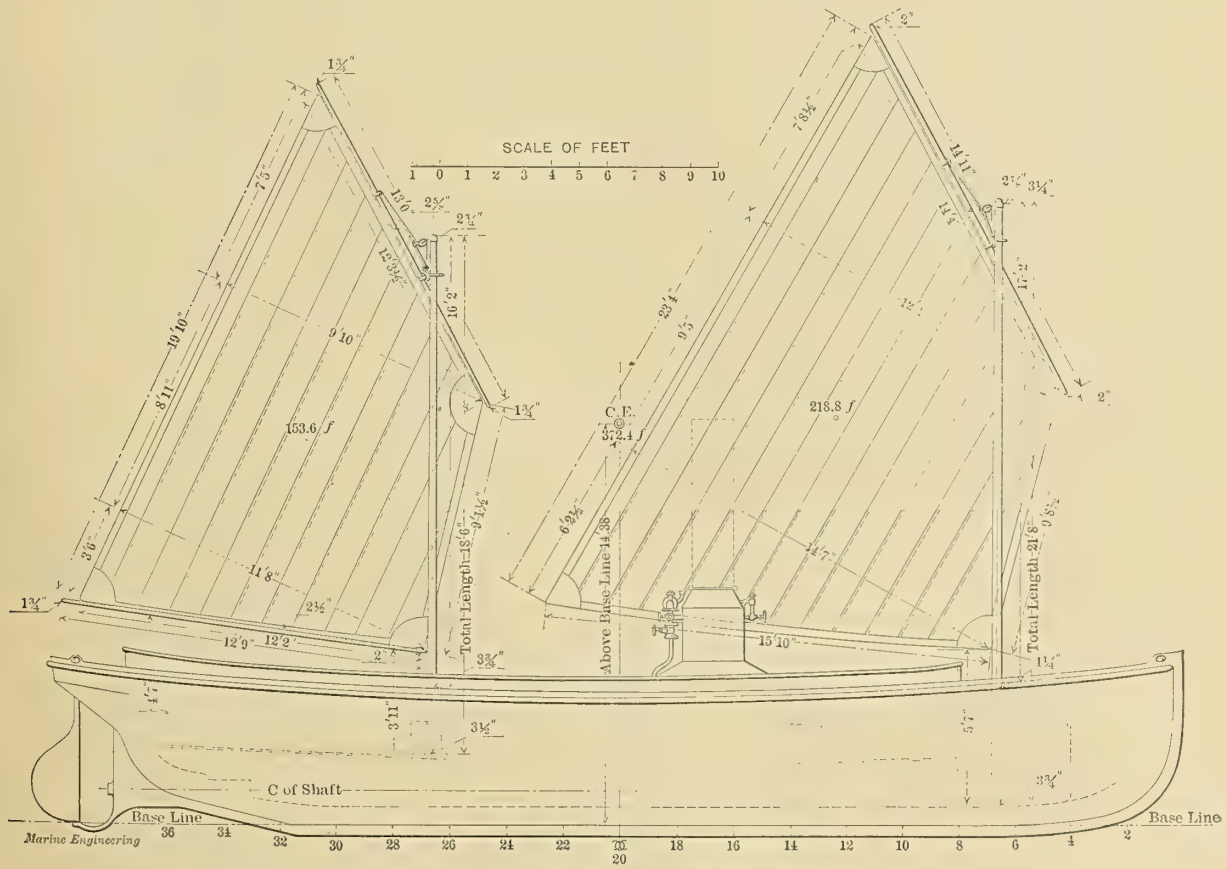
One hundred boats have been built during the past year, and there are now in use in the Navy about 1,000 boats of all classes.

The design of the standard steam cutter is shown in the engravings on pages 10, 11 and 13.

Sail Areas of Standard Boats of the United States Navy.

Type of Boat.		Sail area.	Area of load water line.	Centre of effort from centre of length.	Centre of effort above base.
Steam cutters	40′-0″	372.4	212.8	on ⊗	14.38′
	36′-0″	318.58	182.0	.127′ aft.	13.5′
	33′-0″	301.9	172.5	.046′ "	13.46′
	30′-0″	283.75	145.0	.27′ "	12.64′
	28′-0″	218.82	125.0	.207′ "	11 77′
Launches	33′-0″	505.5	168.5	on ⊗	15.04′
	30′-0″	458.25	152.75	.298′ aft.	13.9′
	28′-0″	390.0	—	.696′ "	11 345′
Cutters	30′-0″	315.0	126.0	.773′ "	12.0′
	28′-0″	290.0	114.75	.696′ "	11.345′
	26′-0″	240.0	94.5	.685′ "	10.647′
	24′-0″	209.0	—	on ⊗	9.79′
Barge	30′-0″	293.75	117.5	.41′ aft.	10.7′
Whale-boats	30′-0″	287.75	111.5	.59′ aft.	10.37′
	26′-0″	260.0	104.0	.52′ "	10.29′
	28′-0″	240.0	96.0	.58′ "	10.08′
	24′-0″	173.65	—	.198′ "	9.55′
Gig whale-boats	30′-0″	236.8	94.75	.449′ "	9.37′
	28′-0″	212.5	85.00	.238′ "	9.43′
Dinghies	20′-0″	134.4	59.7	on ⊗	9.625′
	18′-0″	126.32	56.14	.354′ aft.	9.67′

TABLE III.



Note. No allowance has been made on plan for stretch of sails.

SAIL PLAN OF 40-FT. STANDARD NAVY STEAM CUTTER.

SLIP AND ITS RELATION TO THE PROBLEM OF SCREW PROPULSION.

BY EDMUND LEAVENWORTH.

Let us first try to understand why there is such a thing as *slip*.

The fundamental problem of propulsion is to obtain a thrust whereby the resistance of the ship may be overcome. Let us take first the case of a small boat propelled along a shallow stream by poling over a hard bottom. In such case there is no yield or give to the point of support. The necessary thrust is developed by simply pushing, and the point of support remaining firm, the boat alone yields and is thus urged in the direction desired. Under such circumstances there is an entire absence of the phenomenon of slip.

In the more usual case of propulsion, a like thrust must in some way be developed, but we have now no firm or unyielding support for the propelling agent, and the thrust must be obtained in an entirely different way. Let us see how this is done. It is a fact of universal experience that all bodies tend to maintain their condition of rest or relative motion. This is illustrated at every turn of our every day life. No body at rest can be put into motion, or if in motion can be brought to rest or can have its motion changed, except as it is acted on by a force external to itself. Again, since action and reaction are equal and opposite in direction, any body thus acted on will react on the disturbing agent, and thus produce the manifestation of a force equal and opposite to that required to produce the change. Thus suppose a heavy body hanging at rest by a rope. It requires to set it motion, the exercise of an external force, as the push of the hand, and a resistance is opposed to this motion, which reacts so that the pressure of the body on the hand exactly equals that of the hand on the body. Similarly the body, when once in motion, tends to continue in this condition and requires the manifestation of a force opposed to the motion in order to bring it to rest. It follows from this that if any agent on a ship can produce in matter an increase of motion directed in whole or in part in the direction from forward aft, such agent will be reacted on by a force directed in whole or in part from aft forward, and if the supply of such matter were continuous, such a force might be used as a propulsive thrust. It must be understood that these conditions will be fulfilled by the development of motion sternward in a body originally at rest, by the increase of motion sternward in a body already moving in that direction, or by a decrease, arrest, or reversal of motion in a body moving forward.

Thus a boy standing in a boat and throwing apples or stones over the stern, or a gun firing projectiles sternward, would each give rise to a forward propulsive thrust. Again, a boy in a boat catching apples or balls thrown him from astern would experience likewise a force directed forward, which would thus act as a propulsive thrust. Approaching a step nearer the actual case, we might have a pump on board drawing a continuous supply of water from overboard, and delivering it again overboard, with an accelerated velocity directed aft. In any and all of these cases, matter is so acted on that it is given motion or an increase of motion directed from forward aft, and the attendant reaction furnishes the necessary propulsive thrust. In the last case the plan is perfectly feasible for propulsive purposes, and such methods are occasionally used under the name of "hydraulic propulsion." In the actual propeller or paddle wheel precisely the same fundamental action occurs. In either case a mass of water is taken hold of and given motion sternward. With the screw propeller working at the stern of the ship in the wake, the water when first acted on has already a motion forward. This is arrested and reversed. In all cases, however, the fundamental action is the same, involving, as it does, the use of the *inertia* of the water, and the distinctive difference between gaining a propulsive thrust in this way and by poling over a hard bottom must be clearly noted. It may also be well to point out here more particularly, that it is the *change* brought about by the propeller which is of importance, and not the actual velocity itself. Thus, if the water were moving forward with a velocity of 4 and were stopped and turned backward with a final velocity of 2, the total change would be represented by 6, and the thrust developed would be the same as if the original velocity were 5 forward and final 1 aft, or 1 forward and 5 aft, or originally at rest and finally 6 aft.

It thus appears that the production of a propulsive thrust in this way absolutely requires a change in the sternward motion of the water. Such change is sometimes called the *slip* of the *water*. This, however, is not the slip with which we are here especially concerned, though it has been sometimes confused with it. This slip of the water, however, is accompanied necessarily by a slip of the propeller or paddle wheel; that is, by a difference in the performance of the propelling agent as compared with the case in which there should be no such yield or slip of the water.

Thus, in the case of a screw propeller, if there were no yield to the water considered as the support of the blades, and if the latter thus moved as though supported on a smooth, unyielding surface, the distance moved forward per revolution would equal the pitch as measured on the driving face of the propeller. In the actual case the distance moved per revolution is less than this, and the difference may naturally be called the *slip* of the *propeller*. That is, the propeller slip is the difference between the distance which the ship would move per revolution if the propeller worked on a smooth, unyielding surface, and the distance actually moved per revolution when it works on the yielding water. This is the slip with which we are here particularly concerned.

It should be carefully noted that the slip of the water and that of the propeller are quite distinct in character, and that they are furthermore not equal in amount. Their relationship involves mathematical investigation of a nature unsuited to the present discussion.

The facts thus far established are, therefore, (1) that no propulsive thrust can be developed without a yield or slip in the water, and (2) that this yield or slip will produce an effect on the relation between the geometrical or face pitch of the propeller and the distance moved per revolution.

We must now take another step and define two kinds of propeller slip. It has been defined above as the difference between the pitch of the driving face and the distance moved per revolution. The latter, however, admits of two definitions. The one naturally thought of is the distance relative to the outlying and surrounding body of *still water;* the speed of the ship through the water so called. Of still greater influence, however, on the propeller as an instrument of propulsion is the speed through the water which immediately surrounds it; the speed through the *wake* so called.

It may be well at this point to describe briefly the nature and constitution of the wake. The ship in going through the water sets in forward motion a skin of water, of which that very near the surface moves with nearly the velocity of the ship itself, while as the distance from the surface is increased, the motion correspondingly decreases. The water thus acted on by the skin of the ship is finally found at the stern, where, influenced still further by wave and stream-line motion, it forms the so-called "wake." The forward velocity in the wake at different points in a transverse plane at the stern is quite variable, rising as high as 50 or 75 per cent of that of the ship at points near the stern post at the surface, and decreasing irregularly and gradually to nothing as the outlying water is reached. For single screw ships the average value in that part of the wake directly influenced by the screw is usually found from 10 to 15 or 20 per cent of the speed of the ship. For twin screws, located as they are, not in the strongest part of the wake, the values are usually found between 6 and 10 per cent of the speed of the ship.

Now, to return to the propeller, it is evident that so far as it is concerned individually and simply as a developer of thrust, it should be judged relative to the water immediately about it—relative to the water in which it works and upon which it acts, rather than relative to an outlying body of undisturbed water upon which it has no direct influence. The velocity of the propeller through the wake and the corresponding slip are therefore more closely related to the performance of the propeller as such than the velocity relative to the surrounding still water and the slip corresponding to such velocity. The first is hence known as the *true slip,* while the second is called the *apparent slip.*

Suppose, for convenience, we reckon all velocities relative to the surrounding body of still water. Let u be the velocity of the ship and v that of the wake, reckoned, say, in feet per mt. Then $(u\text{-}v)$ is the speed of the propeller through the wake. Also if p denotes pitch in feet and N revolutions per minute, $p\,N$ would be the speed per minute if there were no slip. Then $p\,N - u$ is the apparent slip and $p\,N - (u - v)$ or $p\,N + v - u$ is the true slip. Denote these two slips expressed in feet per minute by S_2 and S_1, respectively. Then we have:

$$S_1 = pN - u \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$S_2 = pN + v - u = S_1 + v \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

It thus appears that the difference between the two slips is simply the wake velocity, as we should expect. It is customary to reduce S_1 and S_2 to percentages of $p\,N$ as a base, and to speak more particularly of these values as slip ratios or slip per cents. Denoting these by s_1 and s_2 we have:

$$s_1 = \frac{pN - u}{pN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$s_2 = \frac{pN + v - u}{pN} = s_1 + \frac{v}{pN} \quad \ldots\ldots\ldots \quad (4)$$

Very commonly when slip is referred to, apparent slip is intended; though in scientific discussion of screw propulsion, true slip will be more commonly implied. In any case the context will show which of the two is intended, and the fact of the two different kinds, the cause of their difference and their relation should be borne constantly in mind.

We have thus far considered slip as though it were the same for all parts of the blade and for all parts of the revolution. Such, however, is far from being the case. Due to the lack of uniformity in the constitution of the wake, different parts of the blade at any one instant are located in water having different velocities, and any one part of a blade during a revolution is in contact with water having likewise widely differing initial velocities. In consequence, the true slip in any given position of a blade varies from one point to another, while at any given point on the blade it varies during a revolution. Nor are these variations so small that, as is so often the case, we may fairly consider them negligible. From the best information obtainable on the subject, the true slip may vary in this way at different points on the blade and at different parts of a revolution from little or nothing up to 50 or 75 per cent, or, perhaps, even more. It is true that for the most part the slip varies through narrower ranges, but, nevertheless, the variation is very considerable, and in any case is sufficient to entirely destroy the simplicity of meaning which we may attach to the idea of slip in the case of a propeller working in a uniform or undisturbed stream of water.

But there is still another cause which may introduce variability into the slip. This is a variability in the pitch. It is well known that in many propellers the pitch varies from one part of the blade to another in a manner more or less complex according to the *fancy* of the designer. Remembering the way in which pitch is defined, it follows that slip will vary correspondingly, even if the water in which the propeller works is perfectly undisturbed. In all cases where pitch and slip are variable, these terms for the propeller as a whole must be understood as referring to a kind of mean value. We are therefore called upon to define *mean pitch* and *mean slip.* This may be done in several ways according to the manner in which the mean is taken and un-

fortunately there is no generally accepted agreement on this point. Following are some of the ways in which the mean pitch might be defined:

(a) Taking a purely geometrical basis, mean pitch may be defined as the simple mean of a set of distributed values taken over the driving face.

(b) Instead of a simple mean we might perhaps more properly give to the pitch of each element a weight proportional to the work which it absorbs, or to the thrust which it develops. The latter, which is perhaps preferable, may be approximately accomplished by dividing the blade area into a series of elements and multiplying the area of each element by its pitch and by the square of its radius, adding these products, and dividing the sum by the sum of the like products formed by multiplying the area of each element by the square of its radius.

(c) We might also adopt a dynamical basis for the definition of mean pitch as follows: Let the given propeller work in undisturbed water with given revolutions and speed of advance. Let there be a propeller of uniform pitch with the same diameter, area, and shape of blades, and let it work in undisturbed water at the same revolutions and speed. Then the pitch at which the latter propeller would have the same turning moment, or in other words, at which it would absorb the same *work* as the former, may be considered as the equivalent mean pitch. Still otherwise the pitch at which the latter would develop the same *thrust* as the former may be considered as the equivalent mean pitch.

(*To be continued.*)

The ocean going steam yacht Aphrodite, built by the Bath Iron Works for Colonel Oliver H. Payne, of New York, was launched on the Kennebec river, December 1. She was christened by Miss Vivian Scott, daughter of Captain C. W. Scott, who will command the yacht. Our readers will recollect the extensive description, with drawings, of this vessel which we published in our issue of February, 1898. Her dimensions are: Length, 258 ft. L. W. L.; beam, 35 ft. 6 in.; mean draught, 15 ft. She is fitted with a single screw and engines of about 3,000 I. H. P. Her equipment and appointment will be of the very latest and most artistic design.

The hull of the new steam yacht Corsair for J. P. Morgan, of New York, was launched from the yard of T. S. Marvel & Co. at Newburg on the Hudson, last month. She was christened by Miss Louise Morgan, daughter of the owner. This vessel was designed by J. Beavor Webb, and will be fitted with her machinery at the yard of W. & A. Fletcher Co., Hoboken, N. J. The new yacht is 302 ft. long, 33 ft. 3 in. beam, and 23 ft. 6 in. deep. She will be fitted with triple-expansion engines and is expected to be a speedy, seaworthy vessel. The yacht of the same name previously owned by Mr. Morgan was purchased by the Navy Department during the Spanish war, and contributed greatly to the success of the naval fight at Santiago. This vessel was illustrated and described in our issue of August, 1898.

ELECTRICALLY OPERATED 150-TON JIB CRANE AT NEWPORT NEWS SHIPYARD.*

BY WALTER A. POST.

Together with the demands of the day for greater capacity, greater power, and greater speed, as essential characteristics of the modern ship, there comes the dependent feature of greater weight, and, to the shipbuilder, the problem attendant upon this feature, namely, that of providing for the economical handling of these weights.

The plant of the Newport News Shipbuilding and Dry Dock Co., although well provided from its origin with appliances for handling material, was found in its later developments to be in need of apparatus more powerful and more convenient than the 100-ton sheer legs which, to that time, had been used for handling the heavier weights installed on board ships during the fitting-out period.

The growing need of such apparatus had been for some time forcing itself upon the attention of the company, but it was only in the spring of 1896 that it was finally determined to undertake its provision, and steps were taken to ascertain from the experience and opinions of experts, both in this country and abroad, what general type of machine would most satisfactorily fill the particular requirements of the Newport News plant.

The fundamental requirements, briefly stated, were: Capacity to lift and place on board the heaviest single weight liable to be incurred in the probable development of modern ships; a field of operation, as large as practicable, in which these weights could be handled, and absolute precision within this field; a location accessible by the ordinary means of transportation from all parts of the yard; and, finally, that greatest factor defined in all projects by the broadest use of the word economy.

Careful consideration of these requirements lead to the adoption of a 150-ton revolving derrick, electrically operated and controlled, mounted on a steel tower supported in turn by pile foundations. The structure was located on one side of a pier 700 ft. long, forming one side of a slip, in which a number of ships may be moored at one time and readily brought within the field of the derrick's operation. Two standard gauge tracks over entire length of pier afford means of transportation from any part of the yard, and also direct connection to the main lines of the Chesapeake & Ohio R. R. System. The floor of the pier, 185 ft. in width, furnishes ample room for the temporary reception of heavy pieces, castings, armor, etc., and permits, in addition, the assembling of much work within direct reach of the derrick, thus allowing assembled parts to be placed on board as a single member, relieving the tendency to overcrowd floor space in the shops and effect a saving in cost over work as assembled on board ship.

The final design of the derrick was taken up about March 1, 1897, and in July, 1898, sixteen months

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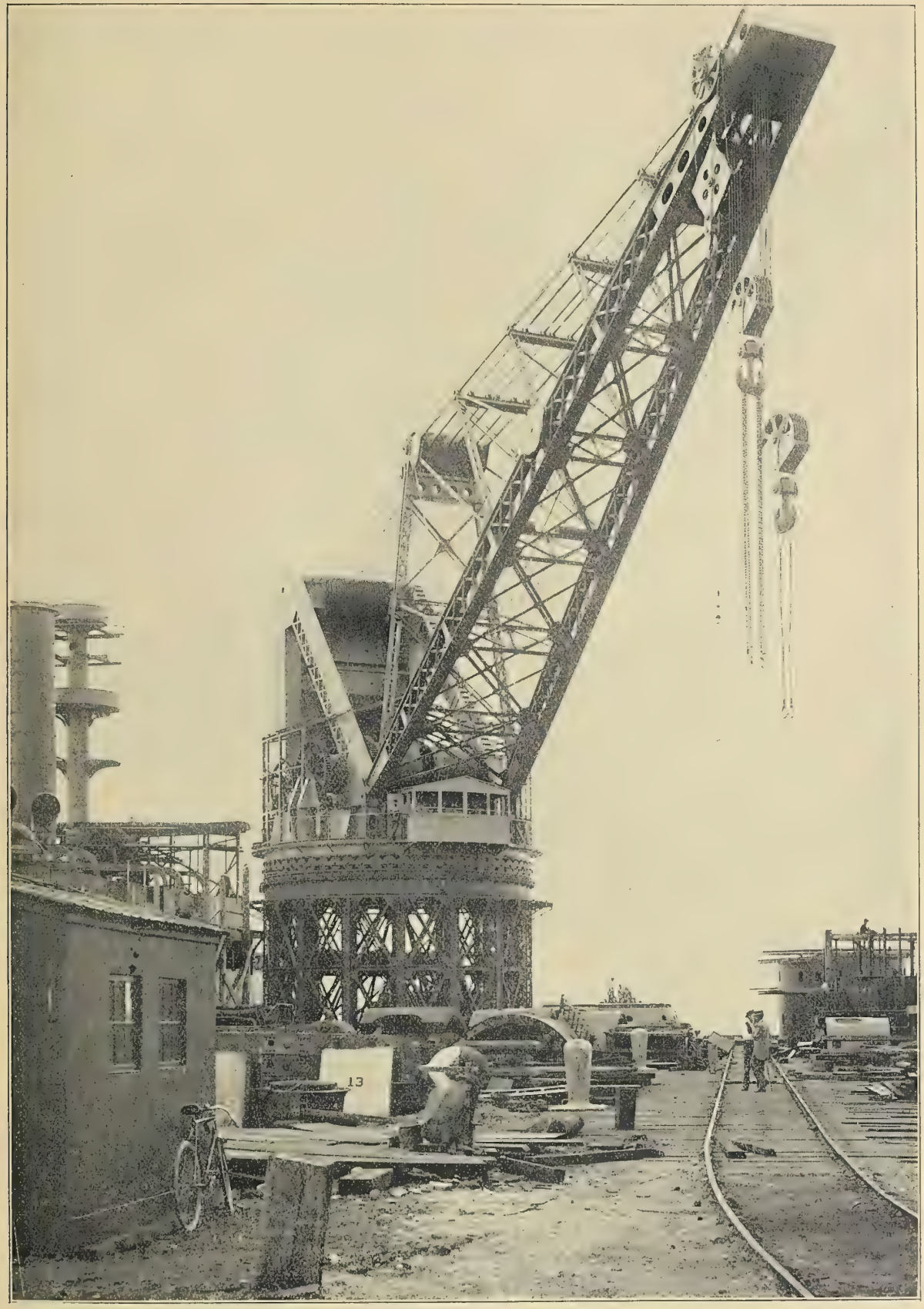
*Read at the Sixth General Meeting of the Society of Naval Architects and Marine Engineers.



150 TON ELECTRICALLY OPERATED JIB CRANE AT NEWPORT NEWS SHIPYARD.

later, weights were being placed on board the battleships in course of construction at the yard.

Aside from the steel work in the tower, it was designed, constructed, and erected by the Newport News Shipbuilding and Dry Dock Co., under the direction of Sommers N. Smith, at that time general superintendent of the works. The design of the derrick itself, including steel tower, jib, hoists, and machinery in general, was prepared by the steam engineering department under C. F. Bailey; the direct working out of plans and details being assigned to R. L. Lovell of the same department. The successful completion and high efficiency of the whole machine attested both the care and skill of the designers and the workmanship of the yard force. The steel tower was furnished and erected by the Berlin Iron Bridge Co., of East Berlin, Conn.; while the foundations were designed and constructed under the direction of the author.

A brief statement as to size, capacity, range of operation, etc., may be of interest before proceeding to the description of particular details.

The derrick jib is capable of having its outer end raised or lowered, thus giving to the hoisting blocks, which depend vertically from this end, a movement not only of rotation about the center of the derrick, but also of translation in or out from this center. With the outer end of the jib in its lowest position the hoisting blocks will, on rotation of the derrick, describe the circumference of a circle 207 ft. dia.; with the jib in its highest position these blocks, on rotation, describe the circumference of another concentric circle 88 ft. in dia., thus permitting the derrick to operate on weights lying anywhere within the circle ring whose maximum and minimum diameters are 207 ft. and 88 ft. respectively. The maximum load of 150 tons can be handled only within a ring whose maximum and minimum diameters are 147 ft. and 88 ft. respectively, but weights up to 70 tons may be handled throughout the entire field of operation. This feature, of varying the radii at which the hoisting blocks can operate, constitutes a most important difference between the derrick under discussion and the 130-ton steam crane erected, in 1893, on Finnieston Quay, Glasgow. In the Finnieston crane, which at the time of its construction represented the ideas of best English practice, there is no variation in the radius at which the hoisting blocks are carried, and, in consequence, the field of operation becomes narrowed to a single line, the circumference of a circle described by the blocks on revolving the crane. The advantages of the Newport News derrick are obvious.

The maximum elevations, above mean high water, for the hoisting hooks in the high and lower positions of the jib are 118 and 69 ft. respectively; this giving ample clearance vertically for any probable conditions.

Taking up the description of the several parts of the structure, it may be well to follow the actual order of construction and begin with the foundations.

A discussion of the conditions which serve to determine the choice between a masonry or pile foundation is obviously beyond the scope of the present paper, and it is sufficient to say that the decision to adopt a pile foundation was reached, not alone after the possibilities of masonry, but also of metal tubes and cylinders filled with cement, had been investigated at much length. The soil at the point of erection is eminently suited to the use of piles, and it is the author's belief, based on a number of years' experience in that locality, that a properly creosoted pile foundation would, under conditions imposed, have about 90 per cent. of its original strength retained after a period of 25 years. Assuming the probable life of the foundation to be 25 years, and recurring again to the governing factor of economy, we may, with pertinence, state that the cost of such foundation was about $8,000, and the time consumed in construction about two months; while the masonry foundation for the Finnieston Quay 130-ton crane cost in the neighborhood of $45,000, and required seventeen months to complete. It is apparent that the interest accumulations on the difference in cost for a period of 25 years is far more than sufficient to renew foundations and re-erect derrick.

The foundations adopted consist of four concentric rows of piles, driven vertically and spaced 3 ft. center to center, measured on the circumference of each ring. One hundred and fifty piles were required for these rings, all carefully selected straight round sticks, measuring not less than 14 in. 6 ft. from the butt, and not less than 9 in. at the small end. They were carefully treated with London ordinary dead oil, of approved quality, 16 lbs. to the cubic foot, and then driven, under a 5,000-lb. hammer, to an average depth of 28 ft. into the hard bottom of the river. In addition to the above, seventy piles were driven at an angle of 30 deg. to the vertical and secured to the capping by galvanized iron drift bolts, thus giving the entire foundation greater rigidity and stability. The caps are carefully selected live oak, 14 in. by 11 in., laid in concentric circles on tops of piles, surmounted in turn by two thicknesses of heavy live-oak flooring, the lower flooring being laid radially across the caps, while the upper one has its lengths laid, similarly to the caps, along the circumferences of concentric circles. The whole assemblage, of caps and flooring, is protected as much as possible from decay, and firmly secured to the piling by galvanized iron drift bolts. It may be well to state, as a concluding remark on the pile foundations, that it is intended to fill the pier solidly around the space occupied by the derrick foundations, thus preserving the piling for an indefinite period from possible attacks of the teredo.

Proceeding to the description of the steel tower:—we have a structure cylindrical in general form, comprised of sixteen columns securely braced and anchored, through their shoe plates, to the pile foundations below, the columns being surmounted by a series of box girders to which is bolted the cast-steel track carrying the rollers on which the derrick revolves. The sixteen columns are equally spaced over the circumference of a circle 36 ft. dia. and set square to radial lines through their centers. They

are built up of two 15-in. channels, 70 lbs. to the foot, well latticed on the sides, with batten plates, top, bottom, and midway their height, at which point horizontal and diagonal braces connect. The column shoe plates are seated on iron plates 1 7-16 in. thick, carried by the upper course of live-oak flooring, each shoe being anchored by twelve 1 3-8 in. bolts to the piles, if possible, and where not, to the pile caps.

To heavy box girders, surmounting the columns, are riveted at every other column the ends of lattice girders projecting radially from the center, at which point they connect to heavy gusset plates which serve to build up a central bearing for the 16-in. vertical pin used to center the derrick, and which serves, also, should unforeseen emergency require it, to prevent any lifting tendency of the derrick itself. Projecting outward and downward from the pin bearing, to the base of each alternate column above mentioned, are stiff angle braces, tied at their middle points to the top and middle point of columns by diagonal and horizontal angles. Diagonal tie rods, 2 in. dia., running from the top and bottom of the alternate columns, which do not carry radial girders, to the bottom and top of corresponding columns opposite, serve, with the above-mentioned angle braces, to rigidly connect and tie together the whole structure of the tower. The circular turned cast-steel track, on which sixty-three conical cast-steel rollers travel, has a mean diameter of 36 ft. for the roller circle and is so beveled that the top elements of the rollers are always horizontal, thus ensuring an easy turning motion. The rollers are held in place by two concentric circular rings, the inner one built up of plates and angle bulb, the outer one of plates alone; these rings being held in place by twenty-one 2-in. steel rods, radiating from the center pin casting, to which they are secured, and passing axially through every third roller and secured at the same time to both roller rings.

We have now reached the revolving structure or derrick proper, which may be, for convenience of description, divided into two members; the housing, a heavily framed structure containing the generating and controlling machinery, operating platform, and counterweight or ballast; to this is secured the second member, namely, the jib, which, carried by the housing and controlled by the power therein, carries in turn the sheaves and blocks through which all the hoisting power must be finally applied.

Recurring to the housing, a brief description will suffice to indicate its general character and note interesting features.

Resting on the conical rollers is a circular girder; on this is carried the heavy cross-girders which furnish supports and foundations for the generating motors, heavy gearing, drums, and other parts of machinery. In a central bearing is the 16-in. pin previously mentioned; at one end of the cross-girders is secured, by a 9-in. pin connection, the lower end of the jib, while at the opposite end of the girders rises the ballast tank containing 410 tons of pig-iron ballast. The ballast tank is built up of heavy floor girders, resting on and running at right angles to the cross-girders above mentioned. From the extremities of these floor girders rise the vertical ends of the tank, each end being a hollow box section and serving to transmit the weight of the ballast from the floor of the tank to the 10-in. pin connections at the top of the tank, from which points inclined struts are run downward and across to the ends of the cross-girders which connect with the lower end of jib. The ballast tank overhangs the circular girder, and as only a portion of the weight of the ballast is required to balance the jib in its high position, the remaining weight of ballast is carried, in that case, by the overhanging girders, which are reinforced by brackets on the side. The arrangement of ballast above described brings the center of gravity of the revolving structure always within a radius of 7 1-2 ft. from the center, which, as the path of the roller bearings has a mean radius of 18 ft., gives a minimum factor of stability of 2.4. Thus, with the jib in its highest position and no load, the c. g. is 7 1-2 ft. behind the center, while with 150 tons load at 73 1-2 ft. radius, or 70 tons load at 103 1-2 ft. radius, the c. g. is 7 1-2 ft. forward of the center. As before referred to, the 16-in. central pin is provided with a top nut and secured below, which thus affords a further safeguard against tilting.

Turning, for a moment, to the jib, attention may be called to the endeavor to so arrange sheaves as to bring the minimum amount of bending and wear upon the pins. The member as a whole is a triangular truss, pin connected and with its long side in compression.

In taking up now the operation of the derrick we will divide our remarks into three headings, corresponding to the three main movements, namely, revolution, elevation or depression of the jib, and the vertical movement of the hoists.

The derrick is revolved by duplicate sets of machinery, each consisting of one No. 800 General Electric railway motor, capable of developing 20 H. P., and driving, through means of a double threaded worm and wheel of the Albro-Hindley pattern, a pinion which, engaging a horizontal circular rack on the outside of the tower, gives the required movement of rotation. The motors are series wound and controlled from a series parallel controller, giving high efficiency under starting conditions as well as at normal speed. The turning motion is very smooth and perfectly noiseless, and, as will be seen from the tests, requires very little power.

The racking movement of the jib is effected as follows: At the inner and upper apex of the jib is a 10-in. steel pin carrying twenty-two cast steel sheaves, each sheave of 5 ft. pitch dia. At the upper apex of the housing is another 10-in. steel pin carrying twenty-four similar sheaves. Leading over these two sets of sheaves, and sustaining the weight of the jib and load, are two 1 1-4-in. steel wire ropes; each rope being wound on alternate sheaves and each end of each rope brought down to separate drums, located below in the housing; this arrangement ensuring freedom from side twisting on the sheaves and also

requiring each rope to take its share of the weight. The four drums, on which these ropes are wound, are arranged in pairs, each one of a pair taking opposite ends of the same rope and each pair driven by a No. 2000 General Electric series motor of 100 H. P.; the power from the motor being transmitted to each drum through a separate train of gears. The drums are of cast iron, 5 ft. pitch dia., carried by 7-in. steel shafts. Each rope, having twenty-two parts, is strong enough to sustain and operate the jib when under maximum load, thus guarding against accident and enabling either motor to be disconnected, and the rope, which it controls, to be removed for repairs or renewal. The motors are series wound, which ensures each taking its proper share of the load.

Passing finally to the hoist, we have two main hoists, each of 75 tons capacity, and one 20-ton whip for lighter loads. The main hoists are each of 12 parts, 1 1-4 in. steel wire rope, leading over six sheaves, 5 ft. pitch dia., carried on a 10-in. steel pin at the outer end of the jib. The lead from these sheaves to the operating drum is carried down the jib on wooden roller runners. These drums, one for each hoist, are of cast iron, 8 1-2 ft. pitch dia., carried on 7-in. steel shafts, and each driven through a train of gears, by a No. 2000 General Electric 100 H. P. motor, series wound. These hoists may be coupled together and operated as one hoist of 150 tons capacity. The 20-ton whip is of three parts, 1 1-4 in. steel wire rope, carrying a single block and leading over two sheaves, carried, as are those for the main hoist, at the outer end of jib. The lead from these sheaves passes down the jib, over a single guide sheave, to a cast iron drum, 8 1-2 ft. pitch dia., driven through a train of gears by a No. 2000 General Electric 100 H. P. motor, series wound.

It will be noticed that electricity is used to generate the power required for all the movements of the derrick. The question involved in the choice as to the form of energy to be employed in such a machine cannot be fully discussed here, but the convenience of operation, ease of movement, and general efficiency of the present derrick attest the successful use of electricity in this case. Current is transmitted, over heavy insulated copper wire, to fixed brushes, attached at the center and near the top of the steel tower. These brushes are arranged to bear against circular contact rings insulated from, but carried by, the center casting to which the roller rods are secured. Near the top of this casting are two more contact rings which transmit the current to a pair of brushes, fixed to the revolving part of the derrick, from which the current is delivered over heavy insulated copper wire to the several motors. The current is delivered to the motors, under normal conditions, at a pressure of 220 volts.

Before concluding, it may be interesting to note a few particular features, and to give the result of such tests as opportunity has permitted up to the present time.

The brakes are a feature of considerable interest. These were required to occupy little space, be powerful and certain in their action, and to be automatic. This was accomplished by extending the ordinary band brake so that it wound four and one-half times around a brake cylinder carried on the shaft to which is keyed the pinion that meshes into the gear of the operating drum. This brings the brake in as direct connection with the load as possible and guards against accidents of the machinery. The brake cylinders are of cast iron, 30 in. dia., with the wearing surface chilled. The band is of wrought iron 1 in. thick, 5 in. wide at one end, and tapering to 1 1-4 in. at the other. The broad end is firmly anchored, while the narrow end is secured to a lever carrying a weight of 200 lbs. When lowering the jib or the hoisting blocks, the direction of rotation for the brake cylinders is toward the small end of the band, so that the friction, produced by the weight, between the cylinder and band, causes the band to wind tight on the cylinder and stop rotation. In hoisting, the brake releases itself, the friction lifting the weight and uncoiling the band; while any tendency to rotate in the opposite direction causes the weight to fall and the band to tighten. To release the brake it is only necessary to lift the weight, which is done by means of a wire connecting with a lever in the operating house; the lever being always within reach of the operator and the brakes always in operation except as released by continuous pull on the lever.

The operating station is directly underneath the lower end of the jib, overlooking directly the weights to be handled, and encased with glass front as a protection against the weather. The controllers for the several motors are within easy reach of a single operator, who is thus given convenient and absolute control over the varied movements of the derrick. The ropes for the hoist and racking movement are all of plough steel wire, 1 1-4 in. dia., of six strands of thirty-seven wires each, with hemp center and very flexible. Each rope has a breaking strength of 100,000 lbs. The gears throughout, except the worms and those supplied with the motors, are of cast steel with cast tenth, the pinions being full shrouded. These gears work very smoothly and show a high efficiency.

The difference in power required for the two main hoists is explained by the fact that all gears, except the pair on motors, have cast teeth and, consequently, variable friction. All tests were made soon after the completion of the derrick, and still better results may be anticipated when opportunity has been given for the gears to wear smooth.

The jib has been both raised and lowered with loads up to 66 tons, but, as this was done only in regular course of work, no data was taken. In hoisting, the required power decreases as the moment of the jib decreases. In lowering, power is required to start the machinery, after which the weight of the jib will keep it in motion.

The variation in speed and power required was probably due to influence of the wind, as the observations were taken on different days, with different velocities of the wind. Tests Nos. 3 and 4, taken as near as possible, show no difference in result, although the position of the center of gravity varied considerably.

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The safety factors attained in the various members are as follows:

For the jib:

Members.	Factors.
Lower struts or legs	10
Tension members—eye bars	9
Inclined struts	7
Wind bracing	12

In hoisting ropes	7
In tower columns	7.5
In tower wind bracing	15

The total weights in long tons are as follows:

Derrick on rollers (no load)	775
Derrick on rollers (maximum load	925
Entire structure on piles (no load)	926
Entire structure on piles (maximum load)	1076
Maximum load for piles, taking vertical piles only and considering eccentricity of loading	9.04

Following is a brief summary of tests:

Tests of the 150 Ton Electrically Operated Jib Crane at Newport News Shipyard.

MOVING JIB.

Movement.	Net load.	H. P.	Time.
From lowest to highest position	0	89.0 to 64.1	6.9 min.
From highest to lowest position	0	0. 0.	5.56 "

HOISTS.

Hoist.	Net load, long tons.	Speed in ft. per min.	H. P. delivered to motor.	H. P. required to hoist load.	H. P. absorbed by mach'y.	Efficiency.
Right-hand main	68	6.05	54.3	28.0	26.3	51.5%
"	0	10.12	29.2	0.	29.2	0.
Left-hand main	66	7.03	61.9	31.4	30.5	50.9%
"	0	9.08	30.65	0.	30.65	0.
Whip	19.2	52.3	88.9	68.3	20.6	76.8%
"	0	84.3	35.35	0.	35.35	0.

REVOLUTION.

No. test.	Net load, long tons.	Total weight on rollers.	C. of G. from center of revolution.	Time of one revolution.	H.P. delivered to motors.
1	134	910	4.28 ft.	3.38 mins.	10.71
2	68	845	2.22 "	3.36 "	11.17
3	0	775	1.47 "	3.04 "	11.15
4	0	775	7.00 "	3.04 "	11.15
5	0	775	4.49 "	3.55 "	10.65

In concluding this paper it may be said that the most difficult problem encountered, in the design of the derrick, was that of providing a safe and efficient way of operating the jib, and, in so far as the author knows, the method adopted is, considering the large forces involved, something of a novelty. The results attained and the efficiency of the mechanism would indicate that the problem had been well solved, and that the idea here carried out might, with advantage, be extended by other designers to future problems.

REMARKS ON THE INDICATOR AS APPLIED TO THE MARINE ENGINE.*

BY W. S. BAILEY.

For the indicator we are indebted to James Watt; and like other of his inventions, such as the governor and the separate condenser, the indicator of to-day, although improved in detail and manufacture, is similar in principle to that used by its inventor. Watt's first indicator consisted of a cylinder about six inches long and an inch in diameter fitted with a tubular piston whose motion was balanced by weights; these weights, however, were soon replaced by a spiral spring as in more recent instruments. At first the surface, a paper-covered board, upon which the pencil acted, was fixed so that the diagram obtained was simply a vertical line whose extremities showed the pressure in the cylinder at each end of the stroke. But, subsequently, the paper-covered board was made to slide in grooves to and fro before the pencil with a motion proportional to that of the engine piston, movement being obtained by a cord attached to some suitable part of the engine, and the sliding board being balanced by a suspended weight. This automatic movement of the board was a great stride forward, because a diagram could now be traced whose length was proportional to the engine's stroke and whose height at every part corresponded to the pressure in the cylinder at that part of the stroke. The presssure on either side of the piston was also shown, with the cut-off, expansion and compression of the steam. The mean pressure throughout the stroke could be calculated; and, from this, the work done by the engine and the proportion of that work to the coal burned.

Watt had, therefore, in his indicator a miniature

*Paper read before the Institution of Engineers and Shipbuilder of Hong Kong.

engine, which showed him graphically the action of the steam within the main cylinder; and crude and imperfect as was the appliance, it greatly assisted him in improving the working of his engines and in illustrating his doctrine of the expansion of steam by enabling him to show that more work could be got from a given amount of steam by expansive working. With higher working pressures and increased piston speeds, the momentum of the indicator's moving parts interfered seriously with the accuracy of the diagrams. Lighter parts and shorter stroke of indicator piston were therefore called for; and with these improvements the name of M'Naught of compound engine fame is identified. M'Naught improved the indicator by increasing the pencil movement through a lever; and to attain a straight line vertical motion of the pencil he adopted in its movement a parallel motion. The principle of securing a wide range of pencil travel with a short piston stroke is maintained in all modern indicators, and is perhaps the greatest improvement ever made in the instrument. The parallel motion, in some form or other, is also maintained to the present day.

With the extensive application of compound engines the indicator came into more general use, that bearing the name of Richards being almost universal in marine practice for many years. This instrument, by Charles B. Richards, may be said to mark an era in the history of the indicator; for being far ahead, both in design and manufacture, of any that had yet appeared, it was extensively adopted. The value of the indicator in estimating horse power for commercial and scientific purposes and by revealing faulty valve settings and other defects became so well appreciated that it seldom was absent on a trial trip of any importance.

The Richards indicator is so familiar as to require little description. The card is secured by clips to a revolving brass drum. The increase of pencil stroke over piston stroke is attained by two pairs of levers pivoted at opposite ends, and connected by a pair of links to whose center is attached the pencil, and near whose inner end is connected the piston rod. The piston of the indicator is exactly one-half of a square inch in area, and its travel is multiplied four times, so that the diagram is four times as high as it would be if the pencil was attached directly to the piston rod. But, with still increasing pressures and piston speeds, the number and weight of the moving parts of Richards' indicator told against it; and it was followed, and to some extent displaced, by the Thompson. In the Thompson indicator the pencil receives motion through a single bar and a simpler arrangement of connecting links, so that the weight and therefore the momentum of the pencil movement is less, and more accurate results are obtained.

The Tabor indicator, following upon the Thompson, represents the best practice of the present day, and may be taken as illustrative of the numerous class of first rate instruments, such as the Crosby and the M'Innes, which compete for our approval, and which show the advances made upon the indicator of Watt. In the Tabor indicator the pencil moves five times as fast as the indicator piston, and a vertical straight line motion of the pencil is obtained by a simple and ingenious device—an upright slotted link on the cylinder cover of the indicator engaging a pin upon the pencil bar. The cylinder cover with its attachments is secured to a separate and outer cylinder, so that the main or internal cylinder, in which the indicator piston works, is less liable to distortion. The springs are duplex, being made of two spiral coils fitted with their points of connection to the caps opposite each other.

Speaking of springs, and as showing the importance of their mode of attachment to the caps, it may be mentioned that in the early days of the Richards indicator, in 1869, the springs (single coil), while correct at one pressure, were found inaccurate at another. Investigation by the makers showed the trouble to be due to the method of securing the springs to the end nuts, the springs being secured at their ends by half a turn, so that the spring was stiffer than it should be, and failed to respond readily to increase of pressure, while, on sudden release from pressure, the reaction of the spring was greater than it should be. Upon the discovery of this error, the springs already issued were recalled and replaced by the makers with correct springs, whose coils were secured to the end nuts by their points only.

Among details of improvement in modern indicators may be noted the small check, or stop, for regulating the pressure of the pencil upon the paper, an important point, both as regards accuracy of the diagrams and quickness and convenience in taking them.

The indicator is not perfect in its action from the fact that, on the one hand, the parts have weight and therefore momentum, which tends to make the diagram larger than it should be, and on the other hand, friction, which tends to make the diagram smaller than it should be. The early Richards, for example, contains also a radical defect in the multiplying movement, the pencil not moving through equal parts of its stroke, while the indicator piston moves through equal parts of its stroke. This is due to the angularity of the link connecting the piston rod to the pencil levers, and which acts in the same way as the connecting rod of an engine in relation to its crosshead; as the pencil is raised or lowered from a horizontal position its travel decreases in proportion to the travel of the indicator piston. In the best instruments this defect has now been greatly modified or entirely overcome; and, although the errors inseparable from momentum and friction cannot be entirely eliminated, they are small, certainly much smaller than other sources of error which will now be considered; and for all practical purposes the indicator is reliable.

Before applying the indicator, it is necessary to use some kind of reducing motion by which the card may be moved through a distance of only a few inches while the engine piston performs its stroke. In marine practice the commonest method of effecting this is by a lever worked from the engine crosshead and pivoted at or near its outer end, the cord being attached to some intermediate point in the lever. The various forms of reducing motion require no detailed

description here, but the lever system of reducing motion contains a serious defect, which is illustrated in Fig. I. The diagram is shown divided into ten

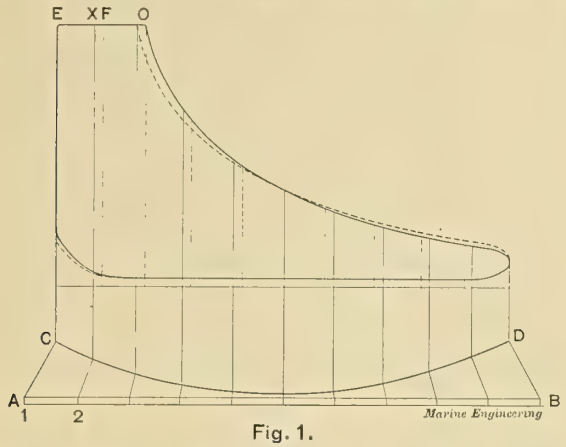


Fig. 1.

equal parts, by dotted lines, and the line A B, representing the engine's stroke, is also divided into ten equal parts. The arc C D represents the path of that point in the lever to which the cord is attached. Now, were the reducing motion perfect, the indicator drum would move through each tenth of its travel, while the crosshead moved through each tenth of its stroke, but this is impossible, because the crosshead moves in a straight line, while the point of the lever to which the string is fastened describes an arc.

Thus: While the crosshead moves from 1 to 2, the drum moves only from E to X, instead of from E to F, and so on throughout the stroke as shown by the unequal distances between the continuous and the dotted lines upon the diagram. There is, however, this difference, that whereas during the first half of the stroke the drum moves through a less proportionate distance than the crosshead, in the latter half of the stroke the drum moves through a greater proportionate distance than the crosshead. The misleading effect of this action upon the diagram is illustrated by supposing the cut-off to take place at O, in which case instead of the true diagram, we would obtain that shown by the dotted expansion and compression lines. The arc C D and the amount of distortion are here produced from actual conditions in a local steamer whose reducing gear is of the telescope style, one rod attached to the crosshead sliding within another pivoted on the engine column, and to whose outer end the cord is connected.

All such reducing motions not only distort the card as shown, but they make the M. E. P. and, therefore, the I. H. P. appear less than they actually are, and in estimating the horse power, etc., from the cards, when a lever reducing motion is used, the amount of error must be determined and allowed for if accuracy is desired. A system of pulleys, the larger of which engages the crosshead and the smaller the indicator cord, gives an accurate drum movement; the only objection to this system being the trouble, and often the difficulty, of fitting the pulleys in suitable positions. Among the best efforts to obtain uniformity of drum movement in indicator gear is that which the late Dr. Kirk fitted to the engines of the Propontis. A twisted flat bar was fixed in bearings parallel to and alongside of the column and on the crosshead an arm was fitted whose projecting end worked over the twisted bar so that as the crosshead moved the bar was partially rotated in the same way as the well-known twist drill brace. A small drum on the end of the bar provided means of connection to the indicator drum and a perfectly proportional movement was obtained.

Returning to the indicator itself. So delicate an instrument is readily affected by even slight derangement, and a few tests may from time to time be applied when engaged in important work. All parts of the indicator and its connections should be as good a fit as is consistent with free action.

(1) To test the freedom of the pencil movement remove the spring and the indicator piston, and see that the pencil falls freely from top to bottom; and with the piston connected, work the pencil up and down to detect any stoppage or gripping. Then with the thumb pressed over the hole through which steam enters the indicator, see that the pencil drops steadily from top to bottom and drops at once upon the thumb being removed.

(2) To test the truth of the drum motion, adjust the stop so that the pencil point is just clear of the drum, and move the pencil slowly from top to bottom and the drum from end to end of its travel to see that the clearance is equal throughout.

(3) Next put a strong spring into the indicator; and taking the pencil between the finger and thumb, press from side to side and up and down to detect any play in the joints.

Before attaching the instrument give the bearings a little oil, especially those which take the strain of the drum upon its spindle; they will fire, and cause the cord to break, if allowed to run dry. The indicator pipes should be of ample size with easy bends, well lagged, and with the cylinder ends clear of the piston at the end of its stroke. It is well to blow the pipes through before connecting the indicator, to remove any dirt or grit which may interfere with its action and cut the cylinder and piston. It sometimes happens that at high speeds the drum spring is too weak to prevent the drum traveling further than it should do, at the end of the stroke, owing to momentum. To detect this error trace the atmospheric line upon the card with the engine going dead slow, and then, lifting the card slightly upon the drum, open the engine to full speed and again trace the atmospheric line. The lines should be of equal length; if they are not equal the diagram will be distorted accordingly, and the cause must be looked for either in the drum itself or in the connections.

We may briefly state the three following conditions of steam before considering its action, as reflected in the indicator diagram:

(1) Dry saturated steam is steam in its best natural state, that is, holding the least possible amount of moisture in suspension while in contact with the water from which it is generated.

(2) Saturated steam is the term used when, owing to priming or imperfectly protected boilers, etc., an excess of moisture exists.

(3) Superheated steam is that which contains more heat than is due to its pressure at formation.

Thus exposed to atmospheric pressure, steam reaches only a temperature of 212 deg., but under a boiler pressure of 160 lbs. it has a temperature of 370 deg.; while if reduced in pressure, it is also reduced in temperature to a corresponding degree, by condensation taking place. Steam has, therefore, a specific temperature for each degree of presssure while in contact with the water of generation, but it may be made to contain more heat than naturally due to its pressure, either by superheating it in the ordinary way or by throttling or wire-drawing it. To illustrate this latter point let us suppose steam of 160 lbs. gauge pressure throttled to 140 lbs. Upon each side of the throttle valve the temperature is 370 deg., although the natural temperature of the steam at 140 lbs. is only 361 deg. This steam is, therefore, as effectively superheated as though its natural temperature had been raised to 370 deg. in a superheater. Strictly speaking, the temperature of the steam after throttling would be slightly less than 370 deg. on account of the internal work done; but the difference is not material to our illustration. We have said that the temperature and the pressure of steam in its natural state always correspond. One cannot alter without changing the other, and it has been proved that steam compressed at atmospheric presssure, while the 212 deg. is maintained, does not increase in pressure, because part of the steam is reconverted into water. And, reversing the process, if the steam be now expanded while the 212 deg. is maintained, the water formerly condensed again becomes steam upon its partial release from pressure. A familiar example of this latter action is afforded by Weir's contact heater and pumps. When the main engines are suddenly slowed or stopped, the water in the heater, being relieved from pressure, boils, causing the pumps to "slam," the water becoming steam of a pressure and a temperature corresponding to the new pressure in the heater. If this new pressure be that of the atmosphere, then the water in the heater resumes its state, as water, at 212 deg.

With this statement of the properties of steam we may consider the indicator diagram, and may compare the diagram obtained by an unstable gas, steam, with that which would be obtained by a perfect gas. Boyle's law, enunciated in 1662, is that "the pressure of a perfect gas at a constant temperature varies inversely as the space it occupies." That is to say, one cubic foot of gas at 100 lbs. pressure when expanded into two cubic feet would be reduced to half its original pressure, or 50 lbs.; if expanded into four cubic feet its pressure would be 25 lbs. and so on.

Fig. 2 shows graphically the expansion of a perfect gas by Boyle's law, the diagram being divided into equal divisions as shown. Cut-off takes place at C, and the gas expands. At 3 its pressure is two-thirds of A B, at 4 two-fourths of A B measured from the perfect vacuum line. A B C D E is an ideal diagram in which A E is the line of perfect vacuum. Pressure is admitted to the piston at the atmospheric line above A, when the indicator pencil rises to a point B, corresponding to the presssure in the cylinder, and the piston begins its forward stroke. On cut-off occurring at C, the gas behind the piston acts expansively to the end of the stroke D. Here the exhaust opens, the pressure falls to the line of perfect vacuum E, and the piston makes its return stroke, at the end of which, at A, the exhaust closes and the steam port opens; the pencil rising to B, as before. In this ideal diagram the effect of clearance on the expansion curve is not shown; the gas is admitted at initial pressure to the point of cut-off; the expansion curve follows Boyle's law; the exhaust opens and closes at the end of the stroke only; the valve is instantaneous in its action, and a perfect vacuum is realized in the cylinder.

In practice none of these conditions are obtainable. Clearance is a mechanical necessity; the boiler pressure is seldom realized in the cylinder, and the action of the valve is not instantaneous. A perfect vacuum is not obtained, nor does the expansion curve agree with Boyle's law. Also for practical reasons, it is necessary to open the exhaust before the end of the stroke, and to close it before the end of the return stroke, so that, instead of the theoretically perfect Fig. 2, we obtain in practice a diagram resembling Fig. 3, in which P V is the line of perfect vacuum;

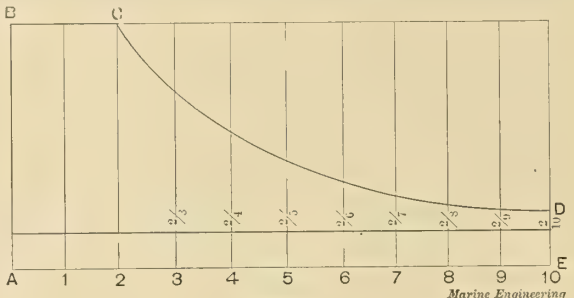


Fig. 2.

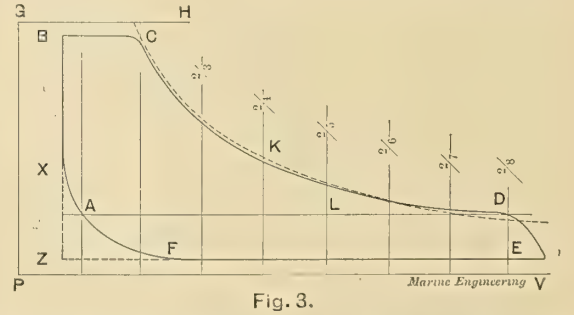


Fig. 3.

A L the atmospheric line; X B the admission line; B C the steam line; C K D the expansion line, and G H the line of boiler pressure. The dotted curve is that due to the application of Boyle's law. At C the steam is cut off and expands behind the piston to D, where the exhaust opens, and the pressure falls to E. The piston performing its return stroke, the pencil traces the back pressure line E F, at the end of which, at F, the exhaust closes and the piston, still returning, compresses the steam shut in the cylinder to a pressure X, the pencil tracing the compression line F X; at X the steam is admitted for the next forward stroke. The distance betwen the vertical

lines X B and P G is the clearance, and this point may be considered more fully. In the theoretical diagram, Fig. 2, the engine is supposed to be without clearance, so that at the point of cut-off the steam to be expanded is simply that contained in the space swept through by the piston. But, in practice, we have not only the space swept through by the piston to the point of cut-off, but also that space occupied by the steam between the piston when at the end of its stroke, and the valve face, that is, the clearance as usually understood added to the volume of one steam port; and this total volume, plus the volume swept through by the piston to cut off, gives the actual volume of steam to be expanded.

Fig. 3 shows a method of laying off the clearance upon the card and of finding the resulting theoretical curve. To find the clearance, the most accurate plan is to place the engine on the center, and having filled in tallow round the edge of the junk ring to prevent leakage into or through the piston, fill the space betweeen the cylinder cover and the valve face with water of a known weight and temperature; the valve must be removed and the steam port covered with a suitable piece of wood smeared with tallow and blocked firmly up to the cylinder face. The water may then be poured in through any opening in the cover, such as the escape valve seat. Having found the weight of water occupying the clearance spaces, convert that quantity into cubic inches, making any necessary correction for temperature. Suppose, for example, the water amounts to 100 cu. in., and that the volume swept through by the piston is 1,000 cu. in.; then the clearance would be one-tenth the volume swept through, and the clearance line must add one-tenth to the length of the diagram. Erect, therefore, the clearance line at this distance upon the card, draw a perpendicular line through the point of cut-off, divide the space between this point and the clearance line into any number of equal spaces, and continue these distances along the diagram, as shown. The theoretical curve may then be found as already described. It is evident that clearance spaces may be a source of loss, because at each revolution they are filled with steam which is exhausted to the condenser or to the line of back pressure without doing work upon the piston. This loss may be largely overcome by closing the exhaust before the end of the stroke as at X in Fig. 3, so that the exhaust steam is compressed to nearly initial pressure, and the incoming steam finds the clearance already filled to a pressure X. Only the quantity of steam X B is now required before the piston moves, instead of the quantity Z B, which would be required were there no compression. Quite apart from economy, as described, compression, by absorbing the inertia of the moving parts, gives a smoothly working enine and reduces the wear of brasses and the oil required. It also reduces the wear and tear of the human element, the engineer, a point which is often lost sight of.

Referring again to Fig. 3, it may be noted that the expansion line C K D falls at first below and afterward rises above the dotted theoretical line; and this enables us to compare the action of steam within the cylinder with that of a perfect gas. In the first place, the boiler pressure never is realized in the cylinder, because of the losses which occur through friction in pipes and passages, and sometimes through wire-drawing by insufficient port opening, etc. Upon entering the cylinder the steam is further condensed by contact with the cylinder walls chilled from the previous exhaust; and to make up for this condensation, and maintain initial pressure to the point of cut-off, supplementary steam is drawn from the boiler. Experiment has proved that on entering the cylinder the steam has suffered condensation to the extent of from 25 per cent to 60 per cent, and that the loss from this cause is greater in slow moving engines, with an early cut-off, than in quick engines with a late cut-off, because, in the latter engines the range of high temperature being better maintained, the cooling due to exhaust is less. When expansion begins, the steam comes in contact with still more chilled cylinder surface; the steam continues to condense; and, being no longer able to draw upon the boiler for compensation, its pressure falls below the theoretical curve, as at K in Fig. 3. At this point we have, besides the steam in the cylinder, sundry films of water clinging to the internal surfaces; and, as expansion proceeds, a point is reached at which the temperature of the steam becomes less than that of the films of water. These latter then evaporate, as in the example of the Weir's heater, the pressure in the cylinder is slightly increased, and the expansion line of the diagram rises above the theoretical line, towards the end of the stroke. Should the expansion line rise much above the normal, we should conclude that steam was being admitteu after cut-off, probably through a leaky valve, while if the actual expansion curve fell below what might reasonably be expected it would indicate a leaky piston, especially if accompanied by a rise in the back pressure line.

The theoretical diagram is more nearly approached in stationary than in marine practice, because with the ordinary link motion it is difficult to obtain the sharp valve action characteristic of the Corliss and similar engines; the comparatively short stroke and greater clearance of marine engines are also against it in the production of the best type of diagram.

Fig. 4 is a diagram from a Corlisss engine, and is selected as an example of how nearly the theoretical curve may be approached in practice and also as showing the indicator's value in depicting this action, and in revealing faulty valve setting. The diagram is in no way intended as a show card, but was taken under every-day conditions to test the working of the engine. The scale of the diagram is 40 lbs. to the inch, and the boiler pressure 80 lbs. by gauge. A is the atmospheric line of the instrument; B the actual vacuum; D the boiler pressure; E the end of the stroke or what should be the admission line; F the long dotted line, the theoretical curve; and G, the finely dotted line, the actual curve. The distance between the lines C and E is the clearance. The admission line by leaning from the perpendicular shows plainly that the steam admission is late, the piston having traveled about 2 1-2 in. at E before it feels the steam properly. This is probably the rea-

son why the steam line is imperfectly maintained and droops somewhat as the piston advances. The cut-off is sharp (sharper than could be obtained with ordinary link motion) and the expansion line is very

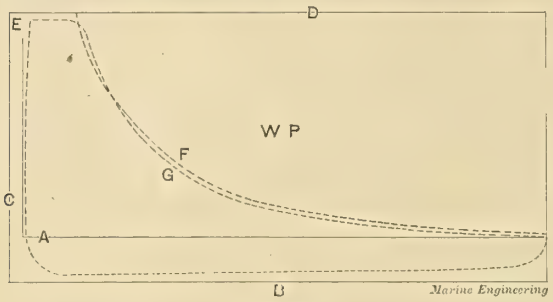


Fig. 4.

good, dropping below the theoretical line as cylinder condensation takes place, and rising as the condensed steam is re-evaporated. The exhaust is late, not opening until the piston reaches the end of its stroke, as shown by the sharp corner at the termination of the expansion curve; and, owing to this late action of the valve, the exhaust gets away with difficulty, and the best effect of the condenser is not obtained until the piston reaches the end of its return stroke. This engine requires the lead increased to make E the admission line; and the exhaust valve should open earlier by about 3 in. of the stroke. This would have the effect of enlarging the diagram at E, and also of increasing the mean effective pressure by allowing the exhaust to get freely away so that the maximum vacuum would be at once realized. By working out the area of the figure which would thus be obtained and comparing it with the present diagram, it may be seen that the area of the diagram, and therefore the power of the engine, would be considerably increased by the slight alterations in valve setting referred to.

Diagrams Nos. *a* and *b*, Fig. 5, are taken from the report of Henry Hillier, chief engineer of the National Boiler Insurance Company of Manchester, England, and they form a pretty good example of the misuse of steam. The diagrams are taken, *a* from one cylinder, and *b* from the other cylinder, of a pair of non-condensing engines working together; boiler pressure 57 lbs. The scale of *a* is 22, and that of *b* 12 lbs. to the inch, and the figures on *a* are those given by the planimeter. Mr. Hillier remarks, "One of the engines was actually doing no work, but was really being driven by the other. One of them they stopped at our suggestion, and the water consumption, as shown by the diagrams, reduced from 66 to 35 lbs. per indicated horse power per hour." These diagrams are peculiar in more respects than one. The first (*a*) is very late in taking steam, and the steam is badly wire-drawn. The expansion lines are wretched and the effective pressure is greater at one end than at the other. Sixty-six pounds of steam per I. H. P. per hour is an outrageous quantity. The other (*b*) is more than peculiar. The steam is admitted, cut off sharply and expanded across the atmospheric line at about one-fifth of the stroke; and those portions of the diagram below the atmospheric line are larger than those above it, so that the engine is doing less than no work, and is actually being pulled round by the other engine. As shown the horse power of *b* is minus 2.5, so that the whole of the steam used in that cylinder is worse than wasted. And in *a*, only 38 lbs. of steam out of 57 lbs. boiler pressure is utilized on the piston, and then not until the piston has been some time on its way, so that the steam never catches it up, and the diagram proves the truth of the old adage that a stern chase is a long one. We do not wonder that when one engine, as Mr. Hillier advised, was stopped the other engine did all the work with less steam.

Fig. 6 is a diagram from the low-pressure cylinder of the compound engine of the steamship Kiung-Chow, and here the effect is seen of a very small volume in the receiver between the cylinders. The expansion line of the L. P. diagram rises in a most unusual manner towards the latter end of the stroke, and this is owing, as stated, to the smallness of the receiver, which consisted simply of a pipe conveying the H. P. exhaust to the L. P. cylinder. When the L. P. piston began its stroke at B, the H. P. exhaust

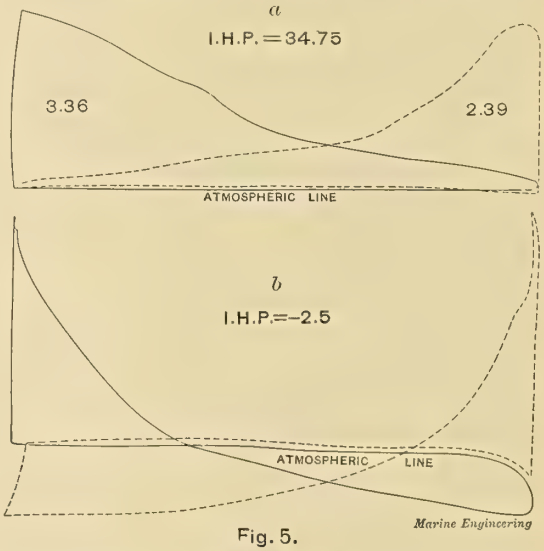


Fig. 5.

was closing, and the contents of the pipe being unable to maintain the pressure in the L. P. cylinder, the pressure dropped to E, and on the H. P. exhaust entirely closing, to C. At C, the exhaust from the opposite end of the H. P. cylinder opened, and the steam port of the L. P. cylinder being also open,

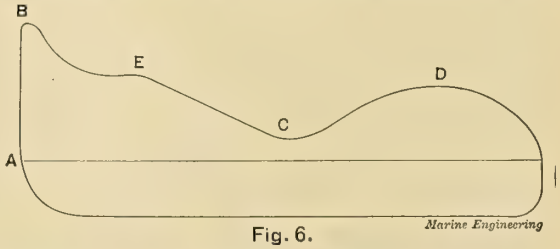


Fig. 6.

owing to the late cut-off, the pressure in the L. P. cylinder rose to D as shown. Cut-off quickly followed by exhaust then took place in the L. P. cylinder and the steam was discharged to the condenser

at a wastefully high pressure. This would have been prevented by an earlier cut-off in the L. P. cylinder.

RESULTS OBTAINED BY THE INDICATOR.

(1) The indicator diagram is a picture of the steam's action in the engine cylinder. From it may be judged the sufficiency of the lead; the point of cut-off; with what degree of perfection the steam pressure is maintained to this point, and the difference between the initial pressure in the cylinder and that in the boiler.

(2) The diagram shows the expansion of steam within the cylinder; at what parts of the stroke the exhaust is opened and closed, and the degree of back pressure upon the piston at every point. The pressure at any part of the piston's stroke and the mean pressure throughout the stroke may be obtained, and from the mean pressure, together with the speed and size of piston, may be calculated the horse power of the engine. The diagram also enables us to compare the actual expansion of the steam with ideal conditions, and affords us approximately the percentages of cylinder clearances.

(3) By combining the diagrams from multiple-expansion engines the drop between each cylinder may be shown, and the difference between the actual curve of expansion and the theoretical curves graphically shown.

(4) By the steam line is shown whether the steam attains its due pressure in the cylinder and is maintained at full pressure to the point of cut-off, or whether, owing to contracted passages or steam pipes, or insufficient port opening, it is wire-drawn, and if so to what extent. The steam line of the intermediate or of the low pressed cylinder also shows the proportion of the receiver capacity to the volume of steam exhausted into it.

(5) By the appearance of the point of cut-off may be seen how nearly the sharp cut-off demanded by economy is approached; while, within certain limits, leakage of valves or piston may be detected by comparing the expansion curve with a theoretical curve or with that of a diagram previously obtained from the same engine when in good order. In paddle steamers fitted with double-beat valves the leakage due to unequal wear of the valves may often, after a few months' work, be detected by the fuller expansion line of the diagram as compared with the cards taken just after the valves had been ground up.

(6) From the position and appearance of the exhaust corners of the card the engineer may judge of the economy of his engine in these particulars; if a quick working engine whether the exhaust opens early enough and whether the compression is in excess of that required for quiet running or whether it may be decreased or increased with advantage.

(7) The back pressure line shows, in a high pressure or intermediate diagram, whether the exhaust opening is sufficient; and in addition to this, in a low pressed card it shows the perfection of the vacuum and with what degree of regularity the vacuum is maintained throughout the stroke. In slow working engines, such as paddle engines, and in which a single-acting air-pump is worked by the engine itself, diagrams taken on the same card from the top and bottom of the L. P. cylinder sometimes appear with one back pressure line higher than the other, showing that on the up stroke of the air pump the vacuum is more perfect than on the down stroke.

(8) In estimating the twisting strain upon shafting the indicator is invaluable, for without it could not be found the strain upon the piston and therefore that upon the shaft. But from the indicator diagram and a knowledge of the speed and weight of the engine's moving parts may be constructed a curve of rotative effort showing the twisting strain upon the shafting at every point of its revolution. By this means the superiority of double over single, of triple over double, and of quadruple over triple cranks is made very apparent as regards their nearness of approach to regularity of crank effort, and a more intelligent idea may be formed of the fitness of the shafting to withstand the strain upon it.

So far the indicator has been considered only in relation to the steam engine cylinder, but it may be applied to the valve casings and motion obtained either from the crosshead or the valve spindle; it may also be applied to the pumps. In these cases its action is similar to that already described, and the figures obtained under various conditions are most interesting and instructive. The diagrams from a pump in good order are usually parallelograms with serrated corners; leakage of the plunger or of the suction valves causes rounding of the corners of the diagrams. Diagrams from pumps, although showing the action of the water within the pump chambers, do not indicate its true pressure if the ordinary springs are used, because these springs are correct only at the temperature of the steam for which they are marked. If used at any other temperature, and accuracy be desired, allowance must be made for the altered temperature, or suitable springs obtained from the makers.

To the indicator and its intelligent use we are largely indebted for our advances in marine engineering. It has been the means of revealing defects of arrangement and construction in the cylinders, valves, passages, etc., thereby apart from economy, improving the working of the engine, and by more uniform motion and better distribution of strain on the working parts, adding to the life of the machine. The indicator has been the means also of confirming the theory of liquefaction and re-evaporation in the cylinders, etc., and it has assisted designers to furnish a better proportioned, more economical, and better running engine. The genius, Watt, that gave to the world a commercially successful motive power, also placed in our hands an instrument which gives at once a measure of that power and an indication of its efficiency.

During the recent Spanish war 4,216 members of the Naval Militia were enlisted in the regular navy.

A favorable report on the Holland submarine boat has been made by a naval board and the boat will soon be subject to an actual war test, firing loaded projectiles at a floating vessel. Should this test be successful the boat will probably be purchased by the Government.

PURCHASE PRICE PAID BY THE NAVY DEPARTMENT FOR WARSHIPS AND AUXILIARY VESSELS ON ACCOUNT OF THE SPANISH WAR.

Abarenda	Abarenda	J. Graham	$175,000
Active	Active	J. D. Spreckles & Co	75,000
Aileen	Aileen	Richard Stevens	55,000
Alicia	Hornet	Henry M. Flagler	117,500
Alice	Alice	John M. Worth	19,000
Almirante Abru	Albany	Brazilian Government	1,205,000
Almy	Eagle	Frederick Gallitin	110,000
Amazonas	New Orleans	Brazilian Government	1,429,215
Atala	Alexander	New Star Blue Line	206,826
Atlas	Wampatuck	Standard Oil Co	65,000
A. W. Booth	Massasoit	Moran Towing Co	30,000
Bristol	Cheyenne	J. J. Cummings	20,000
Celtic King	Celtic	Federal Line	340,900
C. G. Coyle	Chotaw	W. G. Coyle	82,500
Chatham,	Vulcan	Merchants & Miners Line	350,000
Columbia	Wasp	J. H. Ladew	95,000
Comanche	Frolic	H. M. Hanna	115,000
Confidence	Waban	M. Revel	20,000
Corsair	Gloucester	J. Pierpont Morgan	225 000
Creole	Solace	Cromwell S. S. Line	600,000
D. C. Ivins	Nezinscot	Moran & Co	30,000
Diognes	Topeka	Thames Iron Works	170,327
Dorothea	Dorothea	Thos. McKean Est	187,500
East Boston	East Boston	City of Boston	57,500
Ed. Luckenbach	Tecumseh	Luckenbach & Co	45,000
Elfrida	Elfrida	Dr. Seward Webb	50,000
Eliza Holland	Leonidas	Francis Stanley Holland	147,941
El Norte	Yankee	Southern Pacific Co	575,000
El Rio	Dixie	Southern Pacific Co	575,000
El Sol	Prarie	Southern Pacific Co	575,000
El Sud	Yosemite	Southern Pacific Co	575,000
El Toro	Accomac	So. Pacific Co	40,000
Enterprise	Modock	American Towing Co	30,000
Enquirer	Enquirer	W. J. Conners	80,000
Eugenia	Siren	J. G. Cassatt	40,000
Fearless	Iroquois	J. D. Spreckles & Co	150,000
Gov. Russell	Gov. Russell	City of Boston	71,000
Harlech	Pompey	Jas. & Chas. Harrison	111,929
Hercules	Chickasaw	M. Revel	15,000
Hercules	Hercules	Standard Oil Co	40,000
Hermione	Hawk	Henry L. Pierce Est	50,000
Hortense	Takoma	O'Connor & Smoot	28,000
Huntress	Huntress	F. C. Fowler	27,500
Illawara	Oneida	Eugene Tompkins	60,000
Illinois	Supply	International Nav. Co	325,000
Inca	Inca	Frank B. McQuesten	35,080
J. D. Jones	Apache	Merritt & Chapman	54,510
John Dwight	Pawnee	George T. Moon	25,000
Joseph Holland	Hannibal	Francis Stanley Holland	147,941
Josephine	Vixen	P. A. B. Widener	150,000
Justin	Justin	Bowring & Archibald	145,000
Kanawha	Kanawha	John P. Duncan	$50,000
Kate Jones	Seminole	Boston Towboat Co	25,000
Kingston	Cæsar	John Holman & Sons	175,194
Lebanon	Lebanon	Phila. & Reading R. R. Co	225,000
Lucilene	Arethusa	Thomas S. Hopkins	218,992
Mayflower	Mayflower	Ogden Goelet Est	430,000
Menemsha	Iris	Miami Steamship Co	145,000
Merrimac	Merrimac	Hogan Line	342,000
Nanshan	Nanshan	Frank Smythe	155,728
Niagara	Niagara	Ward Line S. S. Co	200,000
Nictheroy	El Cid, Buffalo	Brazilian Government	575,000
No. 18	No. 18	Phila. Trans. & Light Co	2,800
No. 55	Water Barge No. 1	Standard Oil Co	24,000
No. 295	Sylph	John Roach & Co	50,000
Norse King	Rainbow	Thomas Ronaldson	176,576
Not named	Manly	Charles R. Flint	24,250
Not named	Somers	Schichau Iron Works	72,997
Pedro	Hector	A prize capture	200,000
Penelope	Yankton	H. E. Converse	125,000
Penwood	Powhatan	Walsh & Doran	42,500
Peter Jebsen	Brutus	L. F. Chapman & Co	215,000
Philadelphia	Peoria	Phila. Pilot Association	100,000
P. H. Wise	Sioux	Moran & Co	25,553
Port Chalmers	Glacier	Federal Line (London)	340,550
Ravenna	Scipi o	George P. Walford	85,769
Refrigerating Ship			247 704
Restless	Restless	Hiram W. Sibley	29 000
Rhaetia	Cassius	William Lamb	160,594
Right Arm	Pontiac	Merritt & Chapman	30,000
Saturn	Saturn	Boston Towboat Co	290,000
Scindia	Scindia	Henderson Bros	267,657
Shearwater	Shearwater	Henry R. Walcot	26,000
Southery	Southery	Ed. Luckenbach	100,000
Sovereign	Scorpion	M. C. D. Borden	300,000
Sterling	Sterling	Black Diamond Trans. Co	190,000
Stranger	Stranger	Mrs. Mary Lewis	75,000
Sylvia	Sylvia	Edward M. Brown	25,000
Thespia	Hist	David Dows, Jr	65,000
Titania	Marcellus	William Lamb	90,000
T. P. Fowler	Mohawk	Cornell Steamboat Co	44,000
Venezuela	Panther	Red D. Line S. S. Co	375,000
Vigilant	Vigilant	J D. Spreckles & Co	60,000
Viking	Viking	Horace A. Hutchins	30,000
W. A. Luckenbach	Uncas	Luckenbach & Co	75,000
W. H. Brown	Piscataqua	W. H. Brown	130,000
Whitgrift	Nero	McCondray & Co	215,000
Wilmot	Potomac	Ocean Tow and Wrecking Co	125,300
Winthrop	Osceola	Staples Coal Co	100,000
Yorktown	Resolute	Old Dominion S. S. Co	475,000
Yumuri	Badge r	Ward Line S. S. Co	367,000
Zafiro	Zafiro	China and Manila S. S. Co	87,597

In the annual report of Secretary of the Navy John D. Long, the cash prices paid by the Government for warships and auxiliary vessels during the recent Spanish war are given. They are here published in the alphabetical order of the original names of the vessels. During the progress of the war our readers will recollect that we published, from time to time, lists of these vessels giving their chief characteristics and, consequently, by the use of these lists in combination with the above table a brief history of each vessel will be obtainable. In addition to the vessels included in the present list these large ocean liners were chartered: City of Pekin, on the Pacific coast, at $1,000 a day; S. Ss. St. Paul and St. Louis; New York (U. S. S. Harvard) and Paris (U. S. S. Yale), of the American Line, on the Atlantic coast, at $2,500 a day each for the two first named, and $2,000 a day each for the two others. While in the U. S. service these yessels were loaned to the War Department for several days for use as transports. The municipality of Philadelphia loaned an ice boat (U. S. S. Arctic) for the nominal consideration of $1.00, and the steam yachts Free Lance and Buccaneer were loaned for service without charge by the respective owners, F. Augustus Schemerhorn and W. R. Hearst, of New York.

Ship's Bell for U. S. S. Princeton.

Our illustration shows the exceedingly handsome and artistic ship's bell presented to the U. S. S. Princeton by the Alumni of Princeton University at the Navy Yard in Brooklyn, December 10. In addition to this bell a well selected library of 600 volumes, with the necessary cases, and a silver punch bowl were presented to the ship by the Princetonians. In dimensions the gift is rather larger than the regulation ship's bell. It is made of bronze, and is loud and agreeable in tone. Thomas Shields Clark, a Princeton graduate, is responsible for the design, which shows old Nassau Hall in relief with the date of its foundation, 1746, as the central figure. The clapper, above the ring, shows the tiger, typical of Princeton,

BELL PRESENTED TO U. S. S. PRINCETON.

engaged in conflict with the bulldog, typical of Yale; emblematic of the athletic contests between these two great American universities. The presentation address was made by M. Taylor Pyne, of New York, and the bell was accepted in behalf of the ship's company by Commander Clifford H. West, U. S. N. The presentation was made the occasion of a very enjoyable social function.

"THE DOCTOR" AS MET WITH IN WESTERN RIVER STEAMBOAT PRACTICE.

Many of our readers will recollect that more than a year ago we published an extensive description of an Ohio river steamer, the Queen City, as a representative example of western river practice. In describing the machinery of this particular steamer, mention was made that the old-fashioned "Doctor" was missing, the boilers being supplied with feed water by two injectors of the most modern type. These injectors are certainly more easy to handle and occupy considerably less space; but while they can be used to advantage and give the best of satisfaction on the upper portions of the Ohio river, they could not be used in all localities on account of the excessive amount of sand and grit that is held in suspension by the water in certain districts lower down the river. This would cut away the injector tubes so rapidly that they could not be depended upon. For this reason the "Doctor" will hold his own in such localities, and remain a most important detail upon many of the western river steamers.

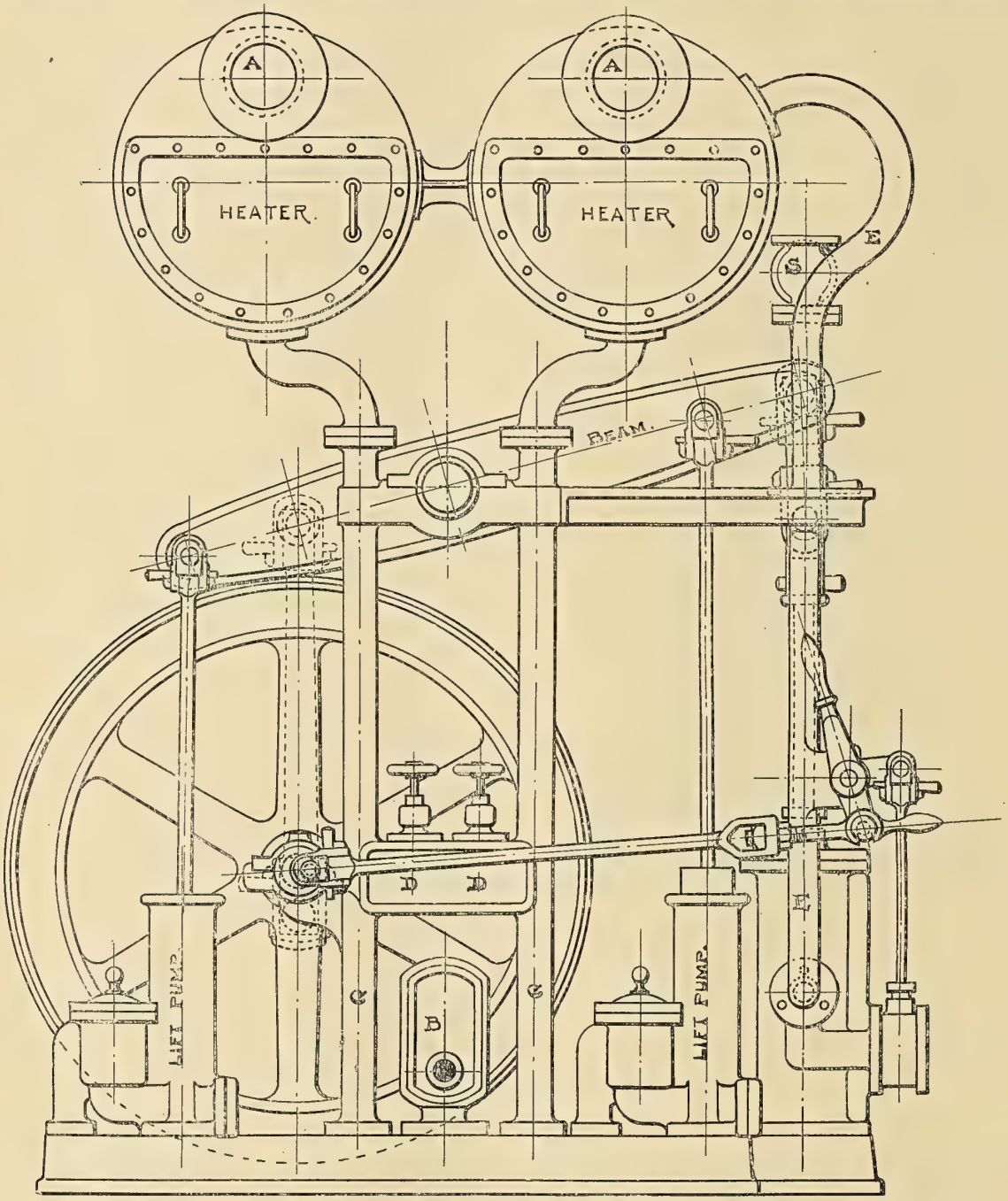
Upon many of the lower river steamers the "Doctor" will be found standing in all of his ancient glory, having Corinthian columns, braced by Gothic arches, forming supports for the overhead working beam and other details; with all of the various connecting rods ornamented with numerous collars, bands, beads and fillets, which testify to the vast amount of time and labor expended upon such work in former times. Occasionally an example is seen where the old style parallel motion is used, in place of the guide and cross head, as well as other reminders of the past. Other types will be found, too, more simple in design, showing that they are of more modern construction.

The "Doctor" shown in the illustrations is one of the "modern school" and consists of a vertical beam engine, with crank and fly wheel, operating four pumps. Two of these are simple lift pumps, drawing water from the river and discharging it into open feed water heaters over head, while the other two are feed pumps taking their supply from the heaters and forcing the water into the main boilers. Each force and lift pump is designed to have ample capacity to feed the entire battery of boilers, so that any one of the pumps may be disconnected for examination or repair without danger, although in practice the machine is more perfectly balanced when all of the pumps are in service.

The base plate, upon which the various details are erected, is deep, and contains numerous ports and passageways which form the water connections between the various parts of the pump. The suction pipe, from the river, is connected with the vacuum chamber B, and communicates through a passage in the base casting with the suction side of the two lift pumps; the discharge from these pumps is also connected by similar passages to the columns C-C, which serve as discharge pipes, beam bearing columns, and heater supports. Near the center of these columns are located valves D-D, which can be closed to prevent the water in the heaters from returning at such times as it is necessary to open up a valve case for examination or repair. The heaters A-A consist of wrought iron shells riveted to cast iron heads through which the exhaust steam from the main engines passes on its way to the exhaust pipes. This exhaust steam comes in direct contact with coils of copper pipe that lie in the lower part of the heaters,

through which the feed water is forced and finally discharged below a diaphragm. Although the diaphragm does not prevent the exhaust steam from coming in direct contact with the water, it acts as a baffle plate and also as an oil separator, being arranged with an overflow pipe which prevents flooding the head of water being sufficient to flood the valves and prevent the feed pumps from missing stroke on account of vaporization of the heated water.

The lift pumps are fitted with long pistons, having cup leather packing in some cases, and in others square gum packing fitted into suitable grooves is



FRONT ELEVATION.

MODERN TYPE OF "DOCTOR" IN SERVICE ON WESTERN RIVER STEAMBOATS.

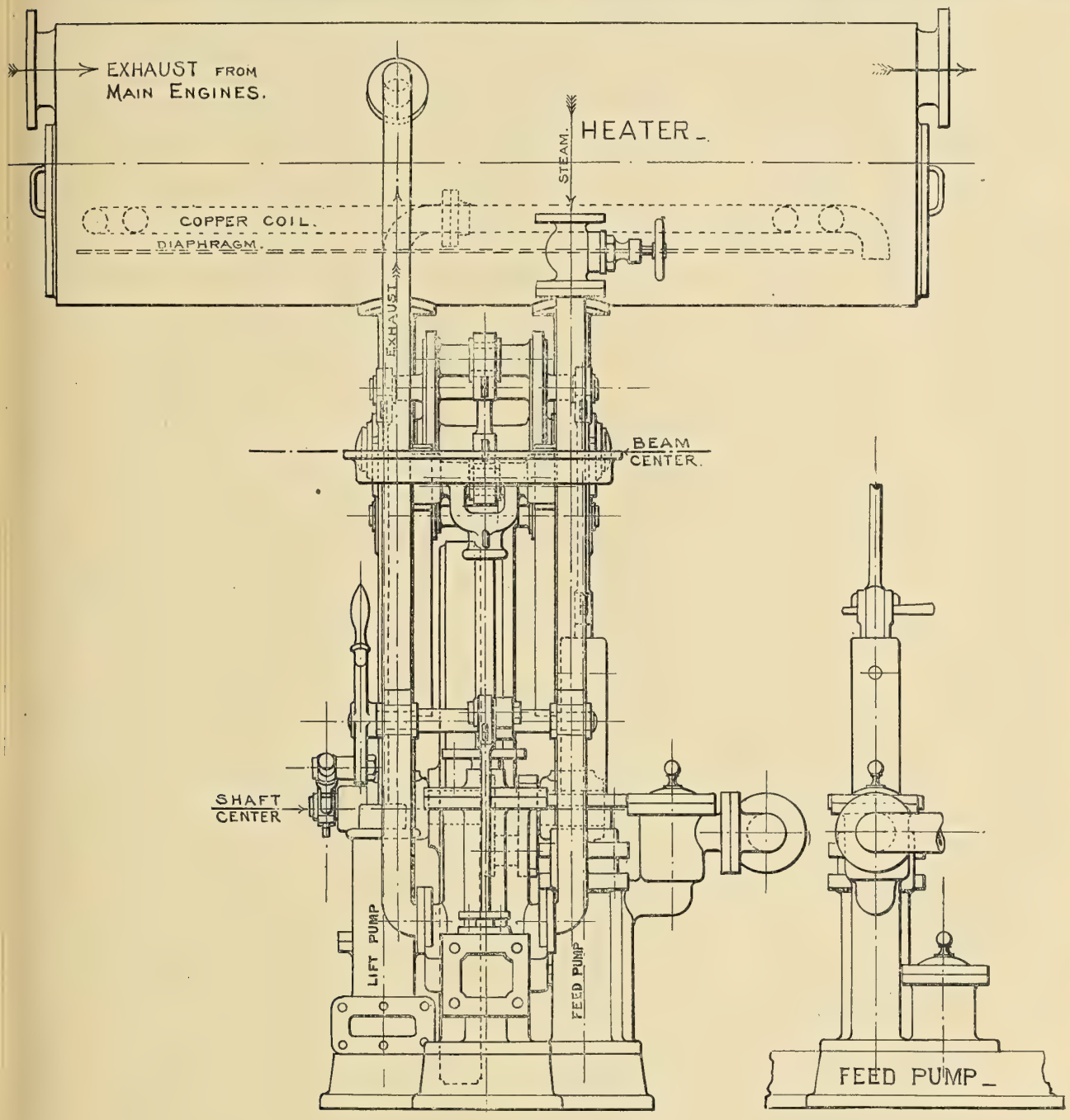
as well as to remove all oil that may float upon the surface of the water.

Upon the opposite side are columns similar to C-C through which the heated water flows to the base plate and to the suction valves of the feed pumps, used, while the feed pumps are arranged with outside packed plungers having deep stuffing boxes and heavy glands fitted to the pump barrels.

The pump valves are flat disks of brass properly guided and fitted to flat brass seats. The valves are

made extra heavy, being 2 1-2 in. thick in some cases, so as to avoid the necessity of springs and at the same time allow ample metal for the purpose of facing off, as it is often found necessary to true up these valves after a round trip.

The engine portion of the outfit is simple in construction, as will be seen by an examination of the drawings, the most noticeable feature in the design being the manner in which the steam and exhaust pipes are utilized to form the supports for the guides upon which the cross head slides. All of the working parts are simple in construction and very accessible, and in the river service, working all kinds of water against high pressures the "Doctor" has proved effective and economical. There is room for improvement, however, and this is a good field in which the manufacturers of high grade steam pumps may show their skill in designing a "Doctor" that will be strictly of the "New School," be more economical than his predecessor, accessible, easy to repair and earn a position which will be at the very head of the "profession" for river service.



MODERN TYPE OF "DOCTOR" IN SERVICE ON WESTERN RIVER STEAMBOATS.

MARINE ENGINEERING

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AN extensive programme for additions to the Navy has been mapped out by Secretary Long, and will in all probability be agreed to by Congress. It contemplates the addition to the Navy of fifteen effective fighting vessels, ranging from battleships of the first class to third-class cruisers, rather larger than the present "Detroit" class. In detail the vessels recommended are:

Three seagoing sheathed and coppered battleships of about 13,500 tons trial displacement, carrying the heaviest armor and most powerful ordnance for vessels of their class, and to have the highest practicable speed and great radius of action. Estimated cost, exclusive of armor and armament, $3,600,000 each.

Three sheathed and coppered armored cruisers of about 12,000 tons trial displacement, carrying the heaviest armor and most powerful ordnance for vessels of their class, and to have the highest practicable speed and great radius of action. Estimated cost, exclusive of armor and armament, $4,000,000 each.

Three sheathed and coppered protected cruisers of about 6,000 tons trial displacement; to have the highest practicable speed and great radius of action, and to carry the most powerful ordnance suitable for vessels of their class. Estimated cost, exclusive of armor and armament, $2,150,000 each.

Six sheathed and coppered cruisers of about 2,500 tons trial displacement; to have the highest speed compatible with good cruisng qualities, great radius of action, and to carry the most powerful ordnance suited to vessels of their class. Estimated cost, exclusive of armament, $1,141,800 each.

It will be noticed that all these vessels are sheathed and coppered, a departure from our regular practice, though one much use in other navies, especially the British. The only vessels of this construction now in our service are the U.S.S. New Orleans, formerly the Amazonas, built in England for the Brazilian Government, and the U.S.S. Albany, now under construction at Newcastle-on-Tyne. This increase to the present fleets built or building would give a total of fifteen first-class battleships, five first-class armored cruisers, six first-class protected cruisers and nine third-class unprotected steel cruisers. The battleships proposed would be considerably larger than those now afloat or even than those recently contracted for. The armored cruisers would be very much larger than either the "New York" or "Brooklyn." The first-class protected cruisers would be rather larger than Admiral Dewey's famous flagship U.S.S. Olympia, and, of course, possessed of many improvements in armor and armament and steaming capacity. The third-class cruisers would be practically a new type, and valuable additions to a class which is now represented by but three modern vessels. Altogether the programme is a well considered one, and if carried out will add greatly to the strength and dignity of the United States in its commercial relations with other maritime countries.

WE have been asked why the Government should expend a large sum of money in the construction of new vessels of the destroyer type, when among the personnel of the Navy there is such an efficient corps of torpedo-boat destroyers? Well, the answer is simple enough: The true mission of a destroyer is to disable or render ineffective the torpedo-boats of the enemy, while the destroyers our questioner refers to are, unfortunately, charged with the operation of our boats, so that instead of a means of offense they become a menace to our fleets. Another gentleman, a member of the Society of Naval Architects and Marine Engineers, who by position and training is well qualified to speak, writes taking exception to a statement made by Lieutenant-Commander W. W. Kimball, U.S.N., in a paper by that officer read before the recent meeting of the Society. This letter will be found elsewhere in these columns. The statement that our correspondent challenges reads:

We have only very few officers of the Engineer Corps competent to give trained engineering super-

vision to those repairs on torpedo-boats which we attempt at Navy Yards, and those few are rarely available for the duty.

We cannot take the serious view of this statement which our correspondent does, and in fact we believe he lays himself open to the charge of a lack of appreciation of humor. Allowing Mr. Kimball's statement about the professional ability or incapability of our engineer officers, is there not a delightful touch of infantile roguishness about his remark? After members of his command had done all in their power (not maliciously, only ignorantly) to render useless the boats intrusted to his care he complains that the engineers are not able to repair them. Just as a child might break his Christmas toy and then blame his parent for not having skill enough to mend it. Even taking our correspondent's view he has, apparently, missed another subtle point of the doughty Lieutenant-Commander's humor, for he has not noted the significance of the word "attempted" in the original. Mr. Kimball does not admit that the Navy Yards can make repairs at all, though he concedes they may "attempt" such repairs. There is a world of difference between repairs "attempted" and repairs "effected." Many a boy with a mechanical turn of mind has "attempted" repairs to the family clock, only to be chastized for his pains. It was unfortunate, however, for Mr. Kimball to indulge in his humor on this point; he must have forgotten the old saying about living in glass houses. The facts in the case can be readily stated. When the Spanish war broke out there was at once felt that lack of trained naval engineers to which Commodore Melville, Engineer-in-Chief of the Navy, had called public attention time and again. So when the torpedo flotilla was assembled in home waters and placed in command of Lieutenant-Commander W. W. Kimball, there was only one engineer officer available for the entire lot of vessels—Passed Assistant Engineer O. W. Koester, U.S.N., who was attached to the "Ericsson." The flotilla consisted of the boats Ericsson, Porter, Rodgers, Dupont, Foote and Cushing. This gave one engineer officer to more than 14,000 indicated horse power of the most delicate machinery afloat. When the war was over and the vessels returned to the Navy Yard the condition they were in is thus described by Chief Engineer Melville in his official report:

> It is a sad fact that nearly every one (torpedo boats) has had some accidents, and the machinery of some at the close of the war was in a condition which can only be described as horrible, where boilers were burnt, cylinder covers broken, pistons and valves stuck, and everything in bad shape. This condition of affairs seems attributable to two causes; the absence of trained engineering supervision, and the use of the boats for duty to which they were not adapted.

What we fail to comprehend is how a commanding officer, Lieutenant-Commander Kimball, in this case, who could get his boats into such an amateurish condition, could consider himself competent to judge of the professional skill of trained Naval Engineers. It looks very much like the cry of "stop thief" which the runaway raises to effect the escape of himself and his associates.

IT speaks much for the patience of the American citizen that no indignant father or brother has laid the restraining hand on Mr. Richmond Pearson Hobson which the Navy Department should have promptly put forth. Has it lost all sense of perspective in gauging the public behavior of its representatives? It is not long since an official court was called to inquire into the purely private and personal matter of an ensign's courtship, which, if unconventional, was manly and within the bounds of strict propriety. Yet we now have the spectacle of an officer, in whose professional attainments the Department has sufficient confidence to originally select him as the director of the post graduate class at Annapolis, on exhibition throughout the country as a public clown. To be sure Mr. Richmond Pearson Hobson sank the "Merrimac" at Santiago, and the ensign, whose name we do not at the moment recall, probably never did anything more than his duty. But if the Department plays favorites it should not forget that the country, which pays for its Navy, has the right to demand that he who wears the uniform of a United States naval officer shall at least conduct himself as a gentleman.

THE selection of Engineer-in-Chief George W. Melville, U.S.N., for the presidency of the American Society of Mechanical Engineers, is a source of great satisfaction to the marine engineering fraternity throughout the country, both naval and mercantile. His grand qualities as a man, his genius as an engineer, and his record as an naval officer are known wherever ships are known, and there is no gift in the profession or out of it that he could not have by vote of the marine engineers of America.

EDUCATIONAL DEPARTMENT.

CALCULATIONS FOR ENGINEERS—AN AID TO CANDIDATES FOR MARINE PAPERS—IV.

BY DR. WILLIAM FREDERICK DURAND.

Formulæ.

A formula is simply a brief way of denoting a series of mathematical operations. Once understood, the directions given by a formula are much more readily followed than when given in the form of a rule. In fact a formula may be considered as simply a brief or short-hand way of expressing the same directions as are given by the rule in ordinary words. In formulæ, quantities are usually represented by letters, as in the well-known horse power formula:

$$I.H.P. = \frac{2\,p\,L\,A\,N}{33{,}000}$$

In this formula p denotes the mean effective pressure per square inch of piston area, L the length of stroke in feet, A the piston area in square inches, and N the revolutions per minute.

In thus writing letters to represent quantities the sign of multiplication, ×, is usually omitted. Thus in the foregoing the numerator $2\ p\ L\ A\ N$ means the same as $2 \times p \times L \times A \times N$, or that the continued product is to be taken of these five factors. It must be noted, however, that where both factors are numbers the sign for multiplication cannot be omitted. Thus, 23 does not mean 2×3, but $20 + 3$ or 23.

Division may be expressed by the usual sign, but it is more commonly indicated by writing the dividend as the numerator and the divisor as the denominator of a fraction. Or in general we multiply by putting a factor in the numerator, and divide by putting a factor in the denominator. Thus in the horse power formula the product $2\ p\ L\ A\ N$ is to be divided by 33,000.

As a further illustration, take the formula

$$p = \frac{T\,t}{6\,R}$$

In this formula p is the pressure per square inch in a boiler, T is the tensile strength of the material of the shell, t is the thickness of the plate, and R is the half diameter or radius of the shell. The whole gives the pressure per square inch allowed by U. S. rules on marine boilers. The formula directs us, in order to find the desired pressure, to multiply together T and t and to divide the product by 6 times R; or, in the words of the U. S. rule: "Multiply one-sixth the lowest tensile strength . . . by the thickness . . . and divide by the radius or half diameter." In this formula all dimensions are in inches and the result is the pressure per square inch allowed on the boiler. Thus let $T = 60{,}000$, $t = 1$ 1-4 in. and $R = 6$ feet or 72 in. Then:

$$p = \frac{60{,}000 \times 1.25}{6 \times 72} = 174 \textit{ pounds per square inch.}$$

Take again the formula

$$p = \frac{112\,t^2}{L^2}$$

In this formula p is the pressure per square inch allowed on a flat surface of a boiler supported by staybolts, t is the thickness of the plate expressed in sixteenths, and L is the pitch of the bolts, or distance from center to center. The formula thus directs us to multiply 112 by the square of the thickness of the plate in sixteenths, and then to divide the product by the square of the pitch of the bolts. Thus let the thickness be 9-16 in. and pitch be 7 in. Then we have:

$$p = \frac{112 \times 9 \times 9}{7 \times 7} = 185 \textit{ pounds per square inch.}$$

As a last illustration take the following:

$$d = \sqrt{\frac{4\,p\,A}{\pi\,K}} + a$$

Such a formula directs us to multiply together $4 \times p \times A$ and then π or 3.1416 by K, and divide the first product by the second, and then take the square root of the quotient. To this we then add the quantity a, and the result is the value of d as desired. Thus if $p = 160$, $A = 100$, $K = 6{,}000$, and $a = .2$, we have:

$$d = \sqrt{\frac{4 \times 160 \times 100}{3.1416 \times 6{,}000}} + .20 = 1.84 + .20 = 2.04$$

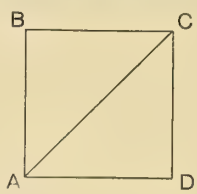
This is a formula for the diameter of piston rod in which d denotes the diameter in inches, p the pressure per square inch of piston area, A the area of piston in square inches, K the safe stress on the material in pounds per square inch of sectional area, and a a small quantity to be added to the result given by the radical.

§ 9. GEOMETRY AND MENSURATION.[8]

[1] Square.

A *square* is a figure, such as $A\ B\ C\ D$, having four sides all equal, and four angles all equal, each being a right angle.

Diagonal, $A\ C$. To find the length of a diagonal, $A\ C$, having given a side of the square, as $A\ B$:



Rule—Square the side, multiply by 2, and take the square root;

$$\text{or } A\ C = \sqrt{\overline{A\ B}^2};$$

or *Rule*—Multiply the side by 1.4142.

Example: $A\ B = 16$. Then $A\ C = \sqrt{2 \times 256} = \sqrt{512} = 22.627$,

$$\text{or } A\ C = 16 \times 1.4142 = 22.627.$$

Area, $A\ B\ C\ D$. To find the area of a square, having given the length of a side, as $A\ B$:

Rule—Square the side, or multiply it by itself;

$$\text{or Area} = \overline{A\ B}^2 = A\ B \times A\ B.$$

Example: $A\ B = 6$. Then area $= 6 \times 6 = 36$.

[8] The following definitions are here given as introductory to this section. Other definitions will be given as the terms are introduced.

An *angle* is formed when two lines, $O\ A$ and $O\ B$, having different directions meet in a point, as O. The angle refers, then, to the difference in direction of the two lines, and its measure is a measure of such difference in direction. An angle is usually denoted by three letters, the one at the apex being placed between the other two. Thus, in *Fig. a* the angle would be called $A\ O\ B$ or $B\ O\ A$.

Fig. *a*.

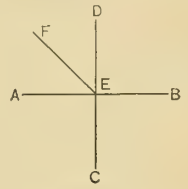


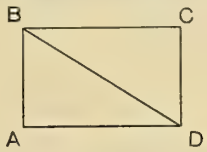
Fig. *b*.

When a line, $C\ D$, meets another line, $A\ B$, in such way that the four angles at E are all equal, the two lines are said to be *perpendicular* to each other, or, in more common terms, one line is square with the other. An angle such as those formed at E is called a *right angle*.

An angle less than a right angle, as $A\ O\ B$, *Fig. a*, is called an *acute* angle. An angle greater than a right angle, as $F\ E\ B$, *Fig. b* is called an *obtuse* angle.

[2] **Rectangle.**

A *rectangle* is a figure, such as $A\ B\ C\ D$, having four sides, the opposite sides being equal and parallel ($A\ B = D\ C$ and $B\ C = A\ D$), and four angles all equal, each being a right angle.



Diagonal, $B\ D$. To find the length of a diagonal, $B\ D$, having given the two sides, as $B\ C$ and $C\ D$:

Rule—Square the two adjacent sides, add, and take the square root;

$$\text{or } B\ D = \sqrt{B\ C^2 + C\ D^2}.$$

Example: $B\ C = 6$, $B\ D = 8$. Then $B\ D = \sqrt{36 + 64} = \sqrt{100} = 10$.

Area, $A\ B\ C\ D$. To find the area of a rectangle, having given the two sides, as $A\ B$ and $A\ D$:

Rule—Find the product of the two adjacent sides;

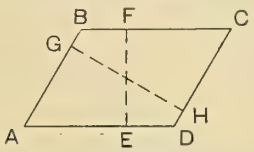
$$\text{or Area} = A\ B \times A\ D.$$

Example: $A\ B = 6$, $A\ D = 8$. Then area $= 6 \times 8 = 48$.

---

[3] **Parallelogram.**

A *parallelogram* is any figure, such as $A\ B\ C\ D$, having four sides and four angles, the opposite sides being equal and parallel, and the opposite angles being equal.



Area, $A\ B\ C\ D$. To find the area of a parallelogram, having given a side and the perpendicular distance between this and the side opposite:

Rule—Multiply one side by the perpendicular distance between it and the side opposite;

$$\text{or Area} = A\ D \times E\ F;$$
$$= \text{also } A\ B \times G\ H.$$

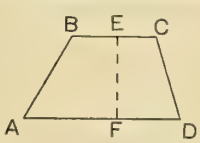
Example: $A\ D = 16$, $E\ F = 9$. Then area $= 9 \times 16 = 144$.

---

[4] **Trapezoid.**

A *trapezoid* is any figure, such as $A\ B\ C\ D$, having four sides and four angles, two of the sides, as $B\ C$ and $A\ D$, being parallel.

Area, $A\ B\ C\ D$. To find the area of a trapezoid, having given the parallel sides and the perpendicular distance between them:



Rule—Multiply the half sum of the parallel sides by the perpendicular distance between them,

$$\text{or Area} = \left(\frac{B\ C + A\ D}{2}\right) \times E\ F.$$

Example: $B\ C = 10$, $A\ D = 16$, $E\ F = 8$. Then area $= \left(\frac{10 + 16}{2}\right) \times 8 = 104$.

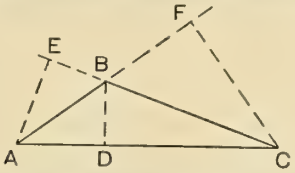
---

[5] **Triangle.**

A *triangle* is any figure, such as $A\ B\ C$, having three sides and three angles. In a triangle placed as in the figure, $A\ C$ is called the *base*, and $B\ D$—the perpendicular distance from B to $A\ C$—is called the *altitude*.

Any Side, $A\ B$. To find the length of any side, having given the triangle complete:

Rule—Square the other two sides and add, and according as the angle between them is greater or less than 90 degrees, add or subtract twice the product of one of these sides by the projection[9] of the other upon it. Then take the square root of the result thus found;



$$\text{or } A\ B = \sqrt{A\ C^2 + B\ C^2 - 2\ A\ C \times D\ C}.$$

$$\text{Similarly } B\ C = \sqrt{A\ B^2 + A\ C^2 - 2\ A\ C \times A\ D},$$

$$\text{and } A\ C = \sqrt{A\ B^2 + B\ C^2 + 2\ B\ C \times B\ E}.$$

Example: $A\ C = 12$, $B\ C = 9$, $D\ C = 8$. Then $A\ B = \sqrt{144 + 81 - 2 \times 12 \times 8} = \sqrt{33} = 5.745$.

Area. To find the area of a triangle, having given the triangle complete, or any side and its perpendicular distance from the opposite vertex:

Rule—Multiply any side by the perpendicular distance from the opposite vertex to such side (produced, if necessary, to meet the perpendicular), and take half the product thus found;
or take half the product of the base by the altitude;

$$\text{or Area} = \tfrac{1}{2}\ (A\ C \times B\ D),$$
$$= \tfrac{1}{2}\ (B\ C \times A\ E),$$
$$= \tfrac{1}{2}\ (A\ B \times C\ F).$$

Example: $A\ C = 120$, $B\ D = 32$. Then area $= \frac{1}{2}$ $(120 \times 32) = 1{,}920$.

[9] Let $B\ D$ be drawn perpendicular to $A\ C$. Then $D\ C$ is called the *projection* of $B\ C$ upon $A\ C$. Similarly $A\ D$ is the projection of $A\ B$ upon $A\ C$, $A\ F$ the projection of $A\ C$ upon $A\ B$ produced, and $E\ C$ the projection of $A\ C$ upon $B\ C$ produced.

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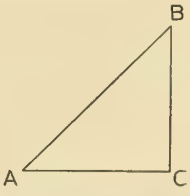
[6] **Right-Angled Triangle.**

In a *right-angled triangle* one of the angles, as C, is a right angle. The side opposite is called the *hypothenuse*.



Hypothenuse, $A\ B$. To find the length of the hypothenuse, having given the other two sides:

Rule—Square the other two sides and add, and take the square root of the sum;

$$\text{or } A\ B = \sqrt{A\ C^2 + B\ C^2}.$$

Example: $A\ C = 9$, $B\ C = 12$. Then $A\ B = \sqrt{81 + 144} = \sqrt{225} = 15$.

Side. $A\ C$ or $B\ C$. To find the length of one of the sides about the right angle, having given the hypothenuse and the other side:

Rule—Square the hypothenuse and the given side. Subtract the squares, and take the square root of the difference;

$$\text{or } A\ C = \sqrt{A\ B^2 - B\ C^2}.$$

Example: $A\ B = 15$, $B\ C = 12$. Then $A\ C = \sqrt{225 - 144} = \sqrt{81} = 9$.

Area, $A\ B\ C$. To find the area of a right-angled triangle, having given the two sides about the right angle:

Rule—Multiply together the two sides about the right angle, and take half their product;

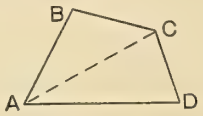
$$\text{or Area} = \tfrac{1}{2}\ (A\ C \times B\ C).$$

Example: $A\ C = 9$, $B\ C = 12$. Then area $= \frac{1}{2}\ (9 \times 12) = 54$.

These rules are special cases of those for the general triangle, as in [5].

[7] **Trapezium.**

A *trapezium* is a figure, such as $A\ B\ C\ D$, having four angles and four sides, no two of the latter being parallel.

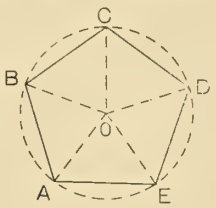


Area, $A\ B\ C\ D$. To find the area of a trapezium, having given the figure complete:

Rule—Divide the trapezium into two triangles, and proceed with each separately, and then add.

[8] **Regular Polygons.**

A *regular polygon* is a figure, such as $A\ B\ C\ D\ E$, having any number of equal sides and a like number of equal angles. They are named as follows:



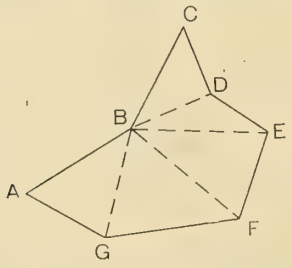
Number of Sides.	*Names.*
3	Triangle
4	Square
5	Pentagon
6	Hexagon
7	Heptagon
8	Octagon
9	Nonagon
10	Decagon

Area. To find the area of any regular polygon; as $A\ B\ C\ D\ E$, having given the figure complete:

Rule—Divide the polygon into as many triangles as there are sides, the apexes all being at the center. Find the area of one of these, and multiply by the number of sides.

[9] **Irregular Figure.**

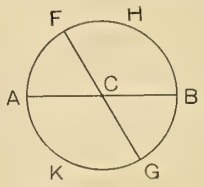
Area. To find the area of a figure, such as $A\ B\ C\ D\ E\ F\ G$, having given the figure complete:



Rule—Divide into triangles in any convenient way; proceed with each separately, and add the results.

[10] **Circle.**

A *circle* is a figure bounded by a curved line, every point of which is equally distant from a point within, called the center. The distance across from one side to the other through the center is called the *diameter* (see $A\ B$ or $F\ G$). The diameter is usually represented by D. The distance from the center to the curved boundary line is called the *radius*, and is plainly one-half the diameter (see $A\ C$, $F\ C$, etc.). The radius is usually represented by r. The curved boundary line, $A\ F\ H\ B$



$G\ K\ A$, is called the *circumference*. Any part of the circumference, as $A\ F$, $F\ H$. etc., is called an *arc*.

Circumference. To find the circumference, having given the diameter:

Rule—Multiply the diameter by 3.1416, or more exactly by 3.1415927, or less exactly by $\frac{22}{7}$. This ratio is frequently denoted by the symbol π,

or Circumference $= 3.1416 \times$ Diameter $= \pi\ D$.

Example: Diameter $= 11$. Then circumference $= 11 \times 3.1416 = 34.5576$.

Diameter. To find the diameter, having given the circumference:

Rule—Divide the circumference by 3.1416, or more exactly by 3.1415927, or less exactly by $\frac{22}{7}$,

or Diameter = Circumference $\div$ 3.1416,
or Diameter = Circumference $\times$ .31831.

Example: Circumference $= 48.7$. Then diameter $= 48.7 \div 3.1416 = 15.50 +$

Area, $A\ H\ B\ K$. To find the area of a circle, having given the diameter or the radius:

Rule—Multiply the square of the diameter by .7854 or $\frac{3.1416}{4}$,

or multiply the square of the radius by 3.1416,

or find half the product of the radius by the circumference,

$$\text{or Area} = .7854 \times (\text{Diameter})^2 = \frac{\pi\ D^2}{4},$$
$$= 3.1416 \times (\text{Radius})^2 = \pi\ r^2,$$
$$= \tfrac{1}{2}\ (\text{Radius} \times \text{Circumference}).$$

Example: Diameter $= 10$. Then area $= .7854 \times 100 = 78.54$.

Length of Arc. To find the length of an arc, as $A\ F$, having given the corresponding number of degrees and the circumference or diameter:

Rule—Divide the circumference by 360, and multiply by the number of degrees in the arc;

or multiply the number of degrees by .008727 and the product by the diameter,

$$\text{or Length } A\ F = \frac{\text{Circumference}}{360} \times (\text{Number of Degrees}),$$

or Length $A\ F$ = (Number of Degrees) $\times$ .008727 $\times$ Diameter.

Example: Find the length of an arc of 60 degrees in a circle whose diameter is 20.

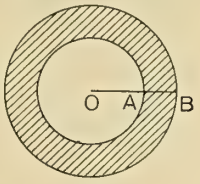
$$\text{Length} = 60 \times .008727 \times 20 = 10.4724.$$

[11] **Circular Ring or Annulus.**

The surface lying between two circles, as shown by the shaded part of the figure, is called a *circular ring* or *annulus*.

Area. To find the area of a circular ring, having given the radii of the two circles:

Rule—Find the difference between the areas of the two circles,

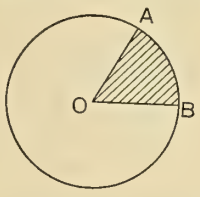


or Area = 3.1416 $\overline{OB}^2$ — 3.1416 $\overline{OA}^2$ = 3.1416 ($\overline{OB}^2$ — $\overline{OA}^2$).

[12] **Sector of Circle.**

The surface lying between two radii and the corresponding part of the circumference, as shown by the shaded part of the figure, is called the *sector* of a circle, or a circular *sector*.

Area, *A B O*. To find the area of the sector of a circle,



having given the corresponding number of degrees and the diameter:

Rule—Find the area of the entire circle, divide by 360, and multiply by the number of degrees in the sector;

or Area = $\frac{\text{Area of Circle}}{360}$ (Number of Degrees in Sector);

or, by proportion, 360° : Number of Degrees in Sector : : Area of Circle : Area of Sector;

or, otherwise, find half the product of the arc by the radius,

or Area = $\frac{1}{2}$ ($O A \times A B$).

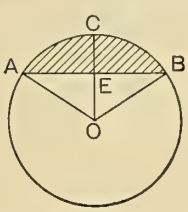
Example: Find the area of a sector of 60 deg. in a circle whose radius is 10.

Area of entire circle = 78.54,

hence Area = $\frac{78.54}{360} \times 60 = \frac{78.54}{6} = 13.09$.

[13] **Segment of Circle.**

A line, such as *A B*, cutting across a circle is called a *chord*. A part of the surface of a circle between a chord



and the circumference, as shown by the shaded part of the figure, is called a *segment of a circle*.

Area, *A C B*. To find the area of the segment of a circle, having given the angle, *A O B*, and the diameter or radius of the circle:

Rule—Find the area of the sector, *O A C B*, as in [12], and of the triangle, *O A B*, as in [5], and subtract the latter from the former;

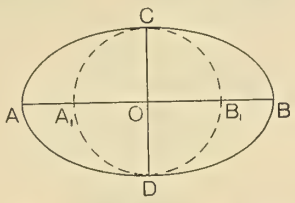
or Area = $\frac{1}{2}$ ($A C B \times O A - O E \times A B$).

Example: $O A = 10$, $O E = 5$, $A B = 17.32$, $A C B = 20.944$,

then Area = $\frac{1}{2}$ (20.944 × 10 — 5 × 17.32) = 61.42.

[14] **Ellipse.**

If the surface of a circle, as shown by the dotted line, be uniformly stretched in one direction (horizontal in the figure) until the diameter, $A_1 B_1$, becomes equal to *A B*, the circumference will be changed into a curved



line, *A C B D*, and the figure thus formed is called an *ellipse*. The two lines, *A B* and *C D*, are called the *diameters* of the ellipse.

Area, *A C B D*. To find the area of an ellipse, having given the two diameters:

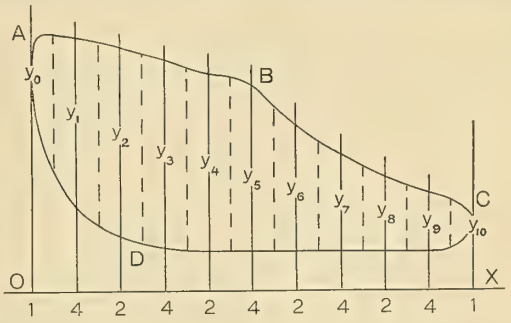
Rule—Multiply the product of the two half diameters by 3.1416,

or Area = 3.1416 × $O C \times O B$.

Example: $O C = 5$, $O B = 8$. Then area = 3.1416 × 5 × 8 = 125.664.

[15] **Figures With an Irregular Contour.**

To find Area, *A B C D*, representing, for example, an indicator card. This cannot be done with absolute ex-



actness, but there are a number of rules for finding the approximate area as closely as we may desire.

Divide the base *O X* into any appropriate number of intervals, usually 10 for an indicator card, and draw lines across the card as shown.

Rule (1)—(*Trapezoidal*). Measure the successive ordinates or breadths on the full lines and from their sum subtract one-half the sum of the end ordinates. Multiply the remainder by the length of the internal or by $O X \div 10$, and the product is the area desired;

or calling the breadth y_0, y_1, y_2, etc., we have by formula in this case.

$$\text{Area} = \frac{O X}{10}(\tfrac{1}{2} y_0 + y_1 + y_2 + y_3 + y_4 + y_5 + y_6 + y_7 + y_8 + y_9 + \tfrac{1}{2} y_{10})$$

As a slightly different and preferable mode of procedure with this rule we may measure the breadths midway between the lines of division as indicated by the dotted lines. Their sum, without modification, is then multiplied by the length of the interval as before.

Any number of spaces as desired may be employed with this rule.

Rule (2)—(*Simpson's or Parabolic*). Measure the ordinates as before.

Take: Once the first and last. Four times every other one beginning with the second. Twice the remaining.

(These multipliers are shown in the figure below the line *O X*.)

Add the products and multiply by one-third the interval, or in this case by $O X \div 30$; or by formula in this case:

$$\text{Area} = \frac{O X}{30}(y_0 + 4y_1 + 2y_2 + 4y_3 + 2y_4 + 4y_5 + 2y_6 + 4y_7 + 2y_8 + 4y_9 + y_{10})$$

With this rule the number of spaces must be even.

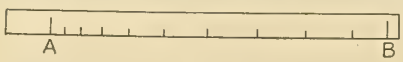
Rule (3)—(*Durand's*). Measure the ordinates as before. To their sum add one-twelfth the sum of those next the end and subtract seven-twelfths of those at the end. Multiply the result by the interval and the product is the area desired;
or by formula in this case:

$$\text{Area} = \frac{O\,X}{10}\left\{\begin{array}{l} y_0+y_1+y_2+y_3+y_4+y_5+y_6+y_7+y_8+y_9+y_{10} \\ +\frac{1}{12}\,(y_1+y_9) \\ -\frac{7}{12}\,(y_0+y_{10}) \end{array}\right\}$$

With this rule any number of spaces as desired may be employed.

The measurement and addition of ordinates as in rules (1) and (3) may be quickly effected by means of a strip of paper on which their lengths are marked off directly from the card and without the use of a scale, joining the end of one to the beginning of the next and thus effecting mechanically the addition desired.

To a reduced scale the strip when marked would resemble *Fig. 16*, the ordinates being as indicated in the



margin. The sum total is then directly found by means of a scale.

Example: Suppose that the ordinates of an irregular area at one-half inch intervals are found by measurement to be as follows in column (1):

	(1) —*Ordinates.*—	(2) *Multipliers.*	(3) *Products.*
y_0	.44	1	.44
y_1	1.42	4	5.68
y_2	1.61	2	3.22
y_3	1.56	4	6.24
y_4	1.51	2	3.02
y_5	1.46	4	5.84
y_6	1.20	2	2.40
y_7	.95	4	3.80
y_8	.71	2	1.42
y_9	.49	4	1.96
y_{10}	.18	1	.18
Sums	11.53		34.20

We then have, according to rule (1):

Sum of ordinates = 11.53
$\frac{1}{2}$ sum of ends... = .31

Difference... = 11.22
Interval ..... = .5

Area = Product = 5.61 square inches.

According to rule (2), we have the multipliers and products as given in columns (2) and (3).

We then have:

Area = $\frac{1}{3} \times .5 \times 34.20 = 5.70$ square inches.

According to rule (3), we have from column (1):

Sum of ordinates ..... = 11.53
$\frac{1}{12}$ sum of next to ends = .16

Sum ..... = 11.67
$\frac{7}{12}$ sum of ends ..... = .36

Difference..... = 11.31

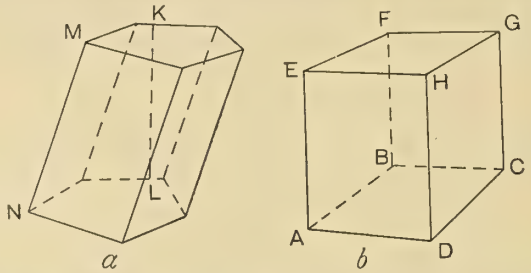
Area = $.5 \times 11.31 = 5.66$ square inches.

Areas of irregular figures, such as indicator cards, etc., may also be found by an instrument called the *planimeter*. In this instrument a pointer is traced around the contour of the figure, while the area is read off from a wheel, which is given appropriate motion by the movement of the pointer. Such instruments, with instructions for use, may usually be obtained from the makers of steam-engine indicators or from dealers in mathematical instruments.

[16] Prism.

A *prism* is a solid body, bounded by two equal and parallel ends and by three or more sides or faces, forming at their junction a like number of parallel edges.

When the sides are perpendicular to the ends, and



are therefore all rectangles, the solid is known as a *right prism*.

When the sides and ends are all squares, the solid is known as a *cube*.

Surface. To find the surface of any prism, having given the figure complete:

Rule—Find the area of the base (or top) by such of the preceding rules as may be appropriate. For the side or *lateral* surface, multiply the *perimeter* or boundary of the base by the perpendicular or shortest distance between any two corresponding lines of the base and top (as *K L* in *Fig. a*).

Volume. To find the volume of any prism, having given the base and altitude:

Rule—Multiply the area of the base or end by the altitude or perpendicular distance between the two ends.

Right Prism. In a right prism the preceding general rules hold, but the lateral faces are all rectangles, and the perpendicular distance between their ends, as *K L*; the length of an edge, as *M N*, and the altitude or perpendicular distance between the ends, all three become equal.

Right Prism, with Rectangular Base. In a solid of this character (see *Fig. b*) the preceding rules still hold, but the sides and ends are all rectangles, and the rules may be simplified as follows:

For the Lateral Surface:

Rule—Multiply the perimeter of the base by the altitude,

or Lateral Surface = Length $A\,B\,C\,D \times A\,E$.

For the Volume:

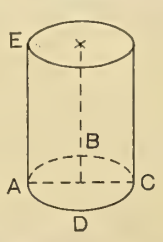
Rule—Multiply together the length and breadth of base and the product by the altitude,

or Volume = $A\,B \times A\,D \times A\,E$.

Example: $A\,B = 8$, $A\,D = 6$, $A\,E = 10$. Then lateral surface = $(8 + 6 + 8 + 6) \times 10 = 28 \times 10 = 280$, and volume = $8 \times 6 \times 10 = 480$.

[17] Cylinder.

A solid with equal circles for base and top, and with a curved lateral surface, is called a *cylinder*. If the center



of the top is vertically over the center of the base, the solid is called a *right cylinder*.

Lateral Surface of Right Cylinder. To find the lateral surface of a right cylinder, having given the diameter of base and the altitude:

Rule—Multiply the circumference of the base by the altitude,

or Lateral Surface = Circumference $A\ B\ C\ D \times A\ E$ = $3.1416 \times A\ C \times A\ E$.

Example: $A\ C = 10$, $A\ E = 20$. Then lateral surface $= 3.1416 \times 10 \times 20 = 628.32$.

Volume of Right Cylinder. To find the volume of a right cylinder, having given the base and altitude:

Rule—Multiply the area of the base by the altitude,

or Volume = Area $A\ B\ C\ D \times A\ E = .7854\ \overline{A\ C}^2 \times A\ E$.

Example: $A\ C = 10$, $A\ E = 20$. Then volume $= .7854 \times 100 \times 20 = 1{,}570.8$.

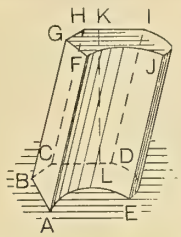
---

[18] **Any Solid with a Constant Section Parallel to the Base, Either Right or Oblique.**

Such a solid is the general case of which the prism and cylinder are but special examples. The rules will therefore be similar to those of [16] and [17].

Surface. To find the surface of such a solid, having given the figure complete:

Rule—Find the area of the base (or top) by such of the preceding methods as may be appropriate. For the side or lateral surface, multiply the *perimeter* or boundary of the base by the perpendicular or shortest distance



between any two corresponding lines of the base and top (as $K\ L$ in the figure);

or Lateral Surface = Length $A\ B\ C\ D\ E\ A \times K\ L$.

Volume. To find the volume of such a solid, having given the figure complete:

Rule—Multiply the area of the base by the perpendicular distance between the base and the top,

or Volume = Area of Base $\times$ Vertical Altitude.

Example: Area of base = 120, altitude = 40. Then volume $= 40 \times 120 = 4{,}800$.

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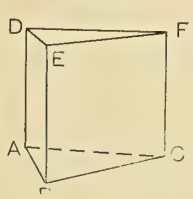
[19] **Wedge.**

A right prism with a triangular base, having two sides equal, as $A\ C$ and $B\ C$, is called a *wedge*.



To find the Surface or Volume, use the same rules as in [16].

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[20] **Right Pyramid.**

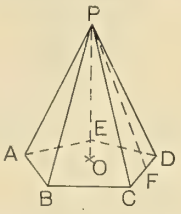
A solid, bounded by a base and by triangular sides meeting in a point or *apex*, as P, is called a *pyramid*. If the base is a regular polygon [8] and the apex is vertically over the center of the base, the solid is called a *right pyramid* (see figure).

Lateral Surface. To find the lateral surface of a right pyramid, having given the figure complete:

Rule—Take one-half the product of the perimeter or boundary of the base by the perpendicular or shortest distance from the apex to one of the sides of the base, as $P\ F$,

$$\text{or Lateral Surface} = \frac{\text{Length } A\ B\ C\ D\ E\ A \times P\ F}{2}.$$

Volume. To find the volume of a right pyramid, having given the base and altitude:



Rule—Take one-third of the product of the area of the base by the altitude, as $P\ O$,

$$\text{or Volume} = \frac{(\text{Area of Base}) \times (\text{Altitude})}{3}.$$

Example: Area of base = 180, altitude = 16. Then volume $= \frac{180 \times 16}{3} = 960$.

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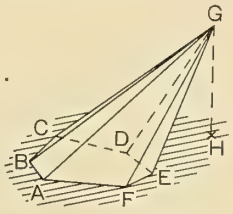
[21] **General Pyramid.**

For definition see [20].

Lateral Surface. To find the lateral surface of any pyramid, having given the figure complete:

Rule—The surface will consist of a series of triangles, similar or not, according to the nature of the pyramid.



These must be computed according to the rules for triangles and the results added.

Volume. To find the volume of any pyramid, having given the base and altitude:

Rule—Take one-third the product of the area of the base by the vertical altitude, as $G\ H$,

$$\text{or Volume} = \frac{(\text{Area of Base}) \times G\ H}{3}.$$

Example: Area of base = 48, $G\ H = 18$. Then volume $= \frac{48 \times 18}{3} = 288$.

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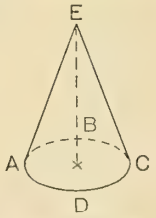
[22] **Right Circular Cone.**

Any solid having a base with curved or irregular boundary, an apex, and straight sides, is called a *cone* in general. If the base is a circle and the apex is verti-



cally over the center, the solid is called a *right circular cone* (see figure).

Lateral Surface. To find the lateral surface of a right circular cone, having given the base and the slant height:

Rule—Take one-half the product of the circumference of the base by the slant height,

or Lateral Surface $= \frac{\text{Circumference } A\ B\ C\ D\ A \times A\ E}{2}$.

Example: Diameter $= 10$, $A\ E = 20$. Then surface $= \frac{3.1416 \times 10 \times 20}{2} = 314.16$.

VOLUME. To find the volume of a cone, as in *Fig. 23*, having given the base and altitude:

Rule—Take one-third the product of the area of the base by the altitude,

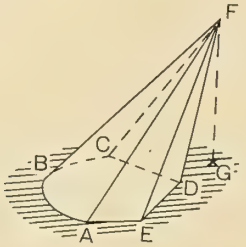
or Volume $= \frac{\text{Area of Base } A\ B\ C\ D \times E\ F}{3}$.

Example: Diameter $= 8$, $E\ F = 15$. Then volume $= \frac{.7854 \times 64 \times 15}{3} = 251.328$.

[23] **General Cone.**

For definition see [22].

VOLUME. To find the volume of any cone, having given the base and vertical altitude:



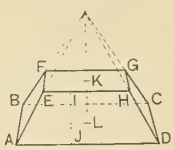
Rule—Take one-third the product of the area of the base by the vertical altitude, as $F\ G$,

or Volume $= \frac{\text{Area of Base} \times F\ G}{3}$.

Example: Area of base $= 240$, $F\ G = 40$. Then volume $= \frac{240 \times 40}{3} = 3{,}200$.

[24] **Frustrum of Right Pyramid.**

The solid contained between the base of a pyramid



and a parallel plane, as $E\ F\ G\ H$, is called the *frustrum* of a pyramid.

LATERAL SURFACE. To find the lateral surface of a frustrum of a right pyramid, having given the figure complete:

Rule—Add the *perimeters* or boundaries of the base and top, and multiply the sum by one-half the perpendicular or shortest distance between two corresponding lines of the base and top, as $I\ J$,

or Lat. Surface $= \frac{(\text{Length } A\ B\ C\ D + \text{Length } E\ F\ G\ H) \times I\ J}{2}$

Example: $A\ B = 10$, $A\ D = 12$, $E\ F = 6$, $E\ H = 7.2$, $I\ J = 5$. Then surface $= \frac{(44 + 26.4) \times 5}{2} = 176$.

VOLUME. To find the volume of a frustrum of a right pyramid, having given the base and top and vertical distance between them:

Rule—Add together the areas of the base and top and the square root of their product, and multiply the sum by one-third the vertical altitude, as $K\ L$,

or Vol. $= \frac{(A\ B\ C\ D + E\ F\ G\ H + \sqrt{A\ B\ C\ D \times E\ F\ G\ H}) \times K\ L}{3}$

Example: Area $A\ B\ C\ D = 100$, area $E\ F\ G\ H = 42$, $K\ L = 12$. Then volume $= \frac{(100 + 42 + \sqrt{4{,}200}) \times 12}{3} = 827.2$.

[25] **Frustrum of General Pyramid, as [21].**

To find the LATERAL SURFACE:

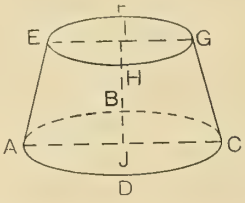
Rule—The surface will consist of a number of trapezoids, similar or not, according to the nature of the frustrum. These must be computed according to [4] and the results added.

To find the VOLUME:

Rule—Same as for [24].

[26] **Frustrum of Right Cone.**

The solid contained between the base of a cone and a



parallel plane, as $E\ F\ G\ H$, is called the *frustrum of a cone*.

LATERAL SURFACE. To find the lateral surface of a frustrum of a right cone, having given the base and top and slant height:

Rule—Add the circumference of the base and top, and multiply the sum by one-half the slant height, as $A\ E$,

or Lat. Surface $= \frac{(\text{Cir. } A\ B\ C\ D + \text{Cir. } E\ F\ G\ H) \times A\ E}{2}$.

Example: Diameter $A\ C = 12$, diameter $E\ G = 10$, $A\ E = 8$. Then surface $= \frac{(3.1416 \times 12 + 3.1416 \times 10) \times 8}{2} = 276.47$.

VOLUME. To find the volume of a frustrum of a right cone, having given the base and top and vertical altitude:

Rule—Same as for [24].

Or in slightly different form, we have the following:

Rule—Add together the square of the upper diameter, the square of the lower diameter, and their product, and multiply the sum by the vertical altitude and by the number .2618,

or Volume $= .2618\ I\ J\ (\overline{E\ G}^2 + \overline{A\ C}^2 + E\ G \times A\ C)$.

Example: $E\ G = 6$, $A\ C = 8$, $I\ J = 4$. Then volume $= .2618 \times 4\ (36 + 64 + 48) = 155$.

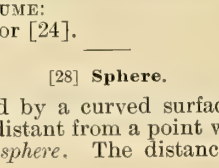
[27] **Frustrum of General Cone, as [23].**

To find the VOLUME:

Rule—Same as for [24].

[28] **Sphere.**

A solid inclosed by a curved surface, every point of which is equally distant from a point within called the center, is called a *sphere*. The distance, $A\ B$, from one



side to the other through the center is called the *diameter*. The distance, $A\ O$, from the surface to the center is called the *radius*, and is plainly one-half the diameter.

SURFACE. To find the surface of a sphere, having given the diameter:

Rule—Square the diameter and multiply by 3.1416,

or Surface = 3.1416 (Diameter)^2.

Example: Diameter = 20. Then surface = 3.1416 $\times$ 400 = 1,256.64.

VOLUME. To find the volume of a sphere, having given the diameter or radius:

Rule—Multiply the cube of the radius by 4.1888, or multiply the cube of the diameter by .5236,

or Volume = 4.1888 $\overline{A\ O}^3$.

or Volume = .5236 $\overline{A\ B}^3$.

[29] **Volume of Irregular Shape.**

Volumes of irregular shape in which the areas of a series of equally-spaced sections may be found.

Rule—Find the areas of a series of equally-spaced cross sections and treat them by the rules given in [15], using areas for ordinates. The result will give the volume desired.

Examples:

(1) Find the volume of an irregular box, 12 feet long; area of one end, 6 square feet; of the other, 15 square feet, and of a section midway between, 10 square feet. The interval is 6 feet.

Then, with Simpson's rule,

Volume = $\frac{6}{3} \times (6 + 4 \times 10 + 15) = 122$ cubic feet.

(2) Find the volume of a coal bunker, 20 feet long, having cross sections every 4 feet, as follows:

Taking rule (3), in [15], we find the result as below:

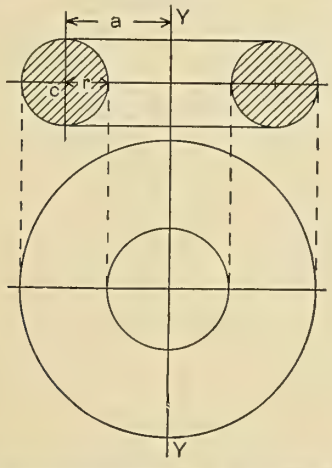
		Square Feet.	
A_0	=	40	297
A_1	=	46	8.3
A_2	=	50	305.3
A_3	=	52	55.4
A_4	=	54	249.9
A_5	=	55	4
			999.6; or, say, 1,000 cubic feet.

[30] **Volume Generated by Any Area Revolving About an Axis.**

Example: TORUS or RING.

SURFACE. To find the surface of a ring, having given the necessary dimensions:

Rule—Multiply the length of the generating line by



the length of the path followed by its center of gravity.

Example, as in the figure.

The length of the generating line is $2\ \pi\ r$.

The length of the path of the center, C, is $2\ \pi\ a$.

The surface is $\therefore\ 2\ \pi\ r \times 2\ \pi\ a = 4\ \pi^2\ a\ r$.

VOLUME. To find the volume of a ring, having given the necessary dimensions:

Rule—Multiply the generating area by the length of the path traveled by its center of gravity.

Example, as in the figure.

The generating area is $\pi\ r^2$.

The length of the path of the center, C, is $2\ \pi\ a$.

The volume is $\therefore\ 2\ \pi^2\ a\ r^2$.

HELPS FOR CANDIDATES FOR MARINE ENGINEERS' LICENSES—FUELS—I.

BY DR. WILLIAM FREDERICK DURAND.

§ 1 COAL.

[1] COMPOSITION AND GENERAL PROPERTIES. The principal fuel for engineering purposes is coal. It consists of the following chief substances:

(A) *Uncrystallized Carbon.*

(B) *Volatile Hydrocarbons.* Hydrocarbons are chemical substances formed of carbon and hydrogen in certain proportions. They often become partially oxidized[1] by the union of part of their hydrogen with oxygen, in the same proportion as in water. Upon the application of heat to the coal they escape in the form of gas, and are hence said to be *volatile.*

(C) *Nitrogen and Oxygen.* These gases, the constituents of air, are also found, the latter in addition to the amount joined to the hydrogen as above referred to.

(D) *Sulphur.* This is found in small amounts, chiefly as a part of the mineral known as *iron pyrites*[2]. The proportion of sulphur is rarely above three per cent and usually much less.

(E) *Ash.* This consists of the earthy and incombustible substances present as impurities in the coal.

Coal may be roughly divided into two chief varieties, *Anthracite* and *Bituminous*, with intermediate grades, *Semi-anthracite* and *Semi-bituminous* occupying the general middle ground between the two. In the present chapter we shall frequently use the terms *anthracite* and *bituminous* as denoting the general division into the two chief varieties, as above noted.

Anthracite coal is sold commercially in hard, compact lumps, showing a shiny, smooth surface when first broken. Bituminous coal is relatively soft and is sold commercially in lumps of irregular size. It crumbles easily, showing often a rather dull surface when broken.

In anthracite coal the proportion of volatile matter varies from 3 to 10 per cent; in semi-anthracite and semi-bituminous, from 10 to 20 per cent, and in bituminous, from 20 to 50 per cent. The amount of ash in good coal should not exceed from 8 to 10 per cent, while occasionally it falls as low as 5 per cent. Anthracite coal is graded commercially, according to size, the chief terms being the following, in the order of increasing size: *Buckwheat, pea, chestnut, stone, egg, broken* and *lump.*

[2] COMBUSTION.

Combustion means simply the chemical union of a substance with oxygen. The oxygen is furnished by the air which contains oxygen and nitrogen. These in air are not in chemical union, but simply as a mixture, in the proportion by weight of twenty-three parts oxygen to seventy-seven parts nitrogen in 100 parts of air. When bodies enter into combustion, or into combustion with oxygen, heat is set free, and the products formed by the combustion are very much hotter than the original fuel and oxygen.

The manner in which coal burns, or enters into combustion, depends upon its composition and upon the nature of the fire and the supply of air. The elements available for the liberation of heat are the carbon and the hydrogen. Small quantities of sulphur are frequently present, but the amount is so small and the heating power so feeble that its influence may be neglected. A pound of pure carbon requires for its complete combustion, 2 2-3 pounds of oxygen, and the result is 3 2-3 pounds of *carbonic acid* or *carbon dioxide* in the form of gas. The total amount of heat set free in this operation is about 14,500 heat units. Now, since the proportion of oxygen in the air is about 23

[1] Oxidised means united with oxygen.

[2] *Iron pyrites* is a mineral formed of iron and sulphur in the proportion of 46.7 parts of iron to 53.3 of sulphur.

per cent, the number of pounds of air required per pound of carbon will be 2 2-3÷.23, or 2.66÷.23, or about 12. Similarly a pound of pure hydrogen requires for its complete combustion, 8 pounds of oxygen, and the result is 9 pounds of water vapor. The total amount of heat set free in this operation is about 62,000 heat units. In the same way as above, it follows that the combustion of a pound of hydrogen will require the presence of 8÷.23, or about 35 pounds of air. The amount of hydrogen, however, is usually small, and allowing for the ash the amount of air necessary to barely furnish the oxygen required for one pound of fuel is about 12, or substantially the same as for one pound of carbon. In practice, however, it is found that this would be insufficient to maintain the draft, nor could we expect that the air would be so distributed as to give exactly the right amount of oxygen at the right place. It is, therefore, necessary practically, to provide a large excess of air and the amount actually passing into the furnaces is usually not less than 18 or 20 pounds per pound of coal, and may even considerably exceed this amount.

Let us now consider the process of combustion with bituminous or semi-bituminous coal. When such coal is put on the fire the first result is not a combustion of the carbon, but a distillation or driving off of the hydrocarbons in the form of gas, and until this operation is nearly completed there will be little or no combustion of the carbon. During this first operation of distillation, heat is absorbed by the fresh coal from the remainder of the fire for the liberation of these gases which are substantially the same as those forming ordinary illuminating gas. After these gases are liberated from the coal they rise into the furnace and combustion chamber. Here, if they meet with a suitable supply of air at a proper temperature, they will be burned, both carbon and hydrogen, and will thus set free all the heat which is obtainable from them. If the air is insufficient in amount the gases will be only partly consumed, the oxygen uniting most readily with the hydrogen and leaving the carbon in fine particles to form *smoke* or *soot*, according as they float away with the products of combustion, or become closely packed together on some of the surfaces of the boiler. If the air is not sufficiently hot likewise, we may have a partial combustion resulting in burning the hydrogen into water vapor and in setting the carbon free as smoke or soot as before. If, however, the temperature is too low the gases may become chilled and pass off as a whole unburnt, thus carrying away not only their own heat of combustion, but also the heat which was absorbed for their liberation. If, on the other hand hydrocarbon gases are subjected to a very high temperature before being mixed with the air, they will become more or less brokn up into free hydrogen and carbon in fine particles. If these are kept at a temperature high enough for ignition and are supplied with oxygen, they will burn; but if they fall below the proper temperature they pass off unburnt, the carbon constituting smoke or soot, as before. Smoke is therefore the sign of a fuel containing hydrocarbons, and of a more or less imperfect combustion. The actual amount of fuel lost in ordinary smoke is, however, very small; so small that it is usually considered as having no significant influence on the question of economy. Hence, smoke prevention is often considered as hardly worth special effort, so far as the saving of fuel alone is concerned. There may be other losses, however, in connection with the general condition of which smoke is an indication, and any mode of design and of general operation which reduces the smoke formation will usually tend toward economy of combustion.

We have already seen that the conditions for burning the hydrocarbon gas are high temperature and an air supply above the grates and in the combustion chamber. We have here, then, one of the reasons for providing openings for the proper admission of air above the grates as well as underneath.

Let us now return to the residue left on the grates after the escape of the hydrocarbon gases. During this part of the operation certain kinds of bituminous coal swell up and cake more or less firmly together on the grate. Such are called *caking* coals. The swelling up is due to the formation of gas in the midst of the coal and to its efforts to escape, while the caking is due to a partial softening or melting of the substance under heat as the hydrocarbons are set free. Other kinds of bituminous coal undergo little change in their external form, while still others break up into small particles or grains. Those latter varieties are called *non-caking* or *free-burning* coals. In any case the residue, after the hydrocarbons are set free, is called coke and consists of nearly pure carbon with ash.

As we have already seen the carbon burns by uniting with oxygen, and this must take place at the burning lump itself. Hence, it is necessary that the air should penetrate thoroughly all parts of the fire, and to this end it is brought in, in part at least, under the grate and by the draft pressure is forced upward through the mass of burning coal. If the fire is rather thick the operation proceeds in the following way. The carbon and oxygen first unite in complete combustion, 1 pound of carbon to 2 2-3 pounds of oxygen, and the product, carbon dioxide, proceeds upward through the fire. As this gas comes in contact, however, with the cooler coal in the midst or near the top of the bed of fuel it absorbs some of the carbon and becomes changed to a combination in the proportion of 1 pound of carbon to 1 1-3 pounds of oxygen. This gas is called *carbon monoxide*. In this operation also is absorbed back again more than two-thirds of the heat which the first combustion had liberated. If the gas should escape unburnt, a serious loss would result, as only about 4,450 heat units or less than one-third of the heat available in the carbon would have been liberated. If, however, the gas finds air above the grate and a suitable temperature, the carbon which was absorbed is burnt out again and the corresponding heat is given back, so that the final result is the completed combustion of the carbon and the liberation of all the heat possible. The formation of carbon monoxide in this way shows again the need of admitting air over the grate, as well as underneath. This gas burns with the peculiar blue flame so often seen, especially after a fresh firing with anthracite coal, and the presence of this flame thus indicates the formation and recombustion of carbon monoxide in the way described. After the coal has all been thoroughly ignited and raised to a bright glowing heat, the combustion into carbon dioxide is completed at once, and there is little or no formation of carbon monoxide to be burned as a gas above the grate. The thinner the fire the more quickly is this condition reached.

The combustion of semi-anthracite and of anthracite coal proceeds in the same general manner as for bituminous coal, except that the period of distillation becomes shorter and less important as the proportion of hydrocarbon is decreased. It thus results that an ordinary anthracite coal burns almost entirely in the manner described for the coke residue of bituminous coal, except than in consequence of the lower temperature of the fuel during the early stages of combustion, there is apt to be a more pronounced formation of carbon monoxide for the combustion of which there must be a supply of air above the grate as already noted.

[3] Impurities in Coal. Clinker Formation. The chief impurities in coal may be divided as follows: (A) Nearly infusible slate, stone, and earthy matter, either in separate lumps or distributed through the coal as a whole, thus giving it a low carbon value. (B) Mineral materials more or less fusible, and thus capable of melting and forming a slag which uniting with the ash and slate forms clinker. Substances liable to be present in coal and which are more or less fusible at the high temper-

atures in the furnaces are: *Potash, soda, lime* and *silica*. The melting point of these substances is also considerably lowered by mixing with iron oxide, which is always formed by the oxidation or combustion of iron pyrites. The presence of this substance in the coal will thus result in lowering the melting point of the other mineral earths and impurities, and in the greater liability to form clinker. This formation of clinker may be so considerable as to seriously interfere with the combustion of the coal, and in such cases its removal must be carefully attended to from time to time in order to keep the fires in good condition.

Iron oxide, or common iron rust as we call it more familiarly, will give to the ashes a reddish tinge so that such a color noted in the ash may usually be accepted as an indication of the presence of iron pyrites in the coal, with the various results which have been already noted. Its presence in any considerable amount is also usually shown by a yellowish or brassy appearance of the coal. For the formation of little or no clinker a coal should have little or no alkali, lime, or pyrites. Such coal in burning gives a nearly white, soft and friable ash.

[4] Weathering of Coal. When coal is exposed to the air and weather for a considerable period of time there is a slow absorption of oxygen, and thus a real combustion and wasting of the fuel value of the coal. It thus results that the coal during this operation is really burning up, though at a rate so slow that the heat developed is hardly appreciable and the change in the outward appearance of the coal is so gradual as to escape ordinary notice. The hydrocarbons are much more readily subject to this operation of gradual oxidation or combustion than pure carbon, the latter entering only with great difficulty into union with oxygen at ordinary temperatures. It thus follows that bituminous coals are much more subject to waste and change by weathering than anthracite coals. In addition to the loss due to this slow combustion there is often a gradual escape of gaseous hydrocarbons imprisoned within the lumps, or a gradual vaporization of liquid hydrocarbons and their escape as vapor. Such losses also are, of course, more marked with bituminous than with anthracite coals. A bituminous caking coal often becomes changed to a non-caking coal after exposure to the air and weather for a considerable period of time.

The chief external conditions which may influence *weathering* are *moisture* and *heat*. If the coal contains no iron pyrites, moisture is believed to slightly retard the operation of slow combustion, and thus to act beneficially rather than the reverse. If iron pyrites is present in the coal, the conditions are changed. Iron pyrites oxidize with comparative readiness at ordinary temperatures, both the sulphur and iron uniting with the oxygen. It thus tends to set up the operation of oxidation and to break up the lump into small bits, while the heat developed is a further aid to the continuance of the process. The oxidation of iron pyrites is, moreover, much aided by moisture, which therefore, with such coals, becomes a distinct disadvantage. In any event a coal with iron pyrites may be expected to suffer more seriously by weathering than one free of this substance. In extreme cases the oxidation of the pyrites has caused the crumbling of the coal into such small bits that it has become nearly worthless for its original purposes.

Heat in general always increases the activity of this slow combustion, and hence tends to increase the loss due to weathering. The heat developed by slow oxidation in the interior of large piles or masses of coal escapes with great difficulty and thus accumulates and raises the temperature, thus making the conditions still more favorable for the continuance of the process. So far as this effect goes, therefore, the loss would be more serious in large piles than in small. This is, however, offset by the greater difficulty which the oxygen has in penetrating to the interior of the pile as it is larger in size. It results that with other things equal there is no great difference in the loss due to weathering with coal either in large or in small bulk.

ELECTRICITY ON BOARD SHIP—PRINCIPLES AND PRACTICE.—XV.

BY WM. BAXTER, JR.

The switch board diagrams, shown in the last article, differ considerably in the manner in which the generators are connected with the line in the act of starting; and, as these relations are of decided importance, it will be well to point out this difference, and at the same time to show what action is liable to follow as a result of defective connections. In Fig. 67 (December, 1898, issue) it will be noticed that the wire marked *c*, which leads from the top brush, is permanently connected with the bus marked *1*, and which, as already explained, is the equalizing bus. Now if the switch *S* of any one of the generators is opened, the connection of wire *c* will not form a closed circuit, because the wire *b* will be disconnected from bus *2*. When a generator is disconnected from the line, it is generally stopped, but if it remains running, the opening of the *S* switch will not prevent a current from circulating through the shunt coils, hence under such conditions it is desirable to be able to open the circuit. It can be accomplished in two ways, one is by moving the switch of the rheostat *R* to a point which breaks the connection, and the other is by opening a separate switch provided for that purpose. The latter arrangement is the best, as then the position of the rheostat switch is not disturbed. When it is desired to connect the generator with the line again it is necessary to close the circuit through the shunt coils and thus allow the machine to develop an E. M. F. equal to that of the other generators before it is thrown in circuit. If this were not done, the result would be that the current from the bus bars would return through the generator if the voltage of the latter were the lowest, and thus convert it into a motor for the time being. In consequence of this action, the engine would be driven not only by its own steam, but also by the power developed by the generator acting as a motor. It is quite evident that under these conditions the speed of the engine would be considerably increased, as its governor could have no effect upon the velocity caused by the action of the motor. If the generator voltage were higher than that of the bus bars, the reverse effect would be produced, that is, the other generators would be driven as motors. In either case the action would be only momentary and, except under extraordinary conditions, not productive of any damage other than a decided disturbance of the line currents. It is necessary, however, to avoid such disturbance and on that account means have to be provided whereby the generator that is to be connected with the line may be brought to the same voltage before it is connected. If we were to connect the shunt coils of the generator only, and adjust the rheostat until the proper pressure were obtained, and then threw the main switch, the result would not be satisfactory; for as can be seen, as soon as this was done, the current developed by the generator would pass through the series coils and thus increase the voltage. It will be clear, therefore, that a current must pass through the series coils before the generator is connected with the line, so that the voltage may be adjusted with the current conditions the same as they will be after the main switch is thrown into the active position. With the connections as shown in Fig. 67 this is accomplished by having an independent switch in the wire *b* by means of which this wire may be connected with bus *2* before switch *S* is turned. When such an arrangement is adopted, the

auxiliary switch is generally located near the generator.

With the type of switch board connections shown in Fig. 68 (December, 1898, issue) the series coils are connected with the bus bars by means of a switch that connects wire *c* with bus *1*, and wire *b* with bus *2*. It is not absolutely necessary to have the wireing connections such that the series, as well as the shunt, coils of a generator can be connected with the line before the generator itself is connected, for it is possible to adjust the voltage to the proper point by making the necessary allowance for the increased effect of the series coils, but in estimating what this allowance should be there is room for serious error, hence the method is not advisable.

In Fig. 69, which represents diagrammatically the switch board of the steamer St. Paul, of the American line, the arrangements for connecting the series coils with the line in advance of the generator are very complete. It will be noticed that there are two switches, marked *S* and *S'*, for each generator. Tracing out the connections of these switches with their respective generators, it will be found that *S* connects with wires *a* and *b* and that *S'* connects with wires *b'* and *c*, the former being a branch of wire *b*. Switch *S'* connects with buses *1* and *2* and switch *S* connects with buses *3*, *4*, *5*, *6*, and *7*. It will be noted that wire *a* of all the *S* switches connects with bus *7*, while wire *b* of each generator connects with a different bus; the object of this arrangement will be made clear presently. The construction of this board is such that four generators can be used continuously while one is held in reserve, the idle machine being the one shown at the extreme left. The wire *b* of this generator connects with the center contact of switch *S1*. If the switches *S* and *S'* of any one generator are opened, the machine will be disconnected entirely from the line. Now suppose it is desired to start up this generator again, then if switch *S'* is closed wire *c* will be connected through it with bus *1* and wire *b* with bus *2*, the former connecting through wire *c'* and the latter through wire *b'*. By the closing of switch *S'*, therefore, the series coils of the generator are connected in parallel with those of the other machines, and on this account will be traversed by a current of the same strength. Under these conditions the E. M. F. developed by the armature will be nearly the same before switch *S* is closed, as after, for in both cases the current through the series coils will be the same, and so will that through the shunt coils. As a matter of fact the E. M. F. will be slightly lower after switch *S* is closed, owing to the fact that then a larger current will flow through the armature and as a result the extra voltage absorbed by the armature resistance will have to be deducted from the total E. M. F. This reduction, however, will be small and will only result in causing the generator to develop less than its proper

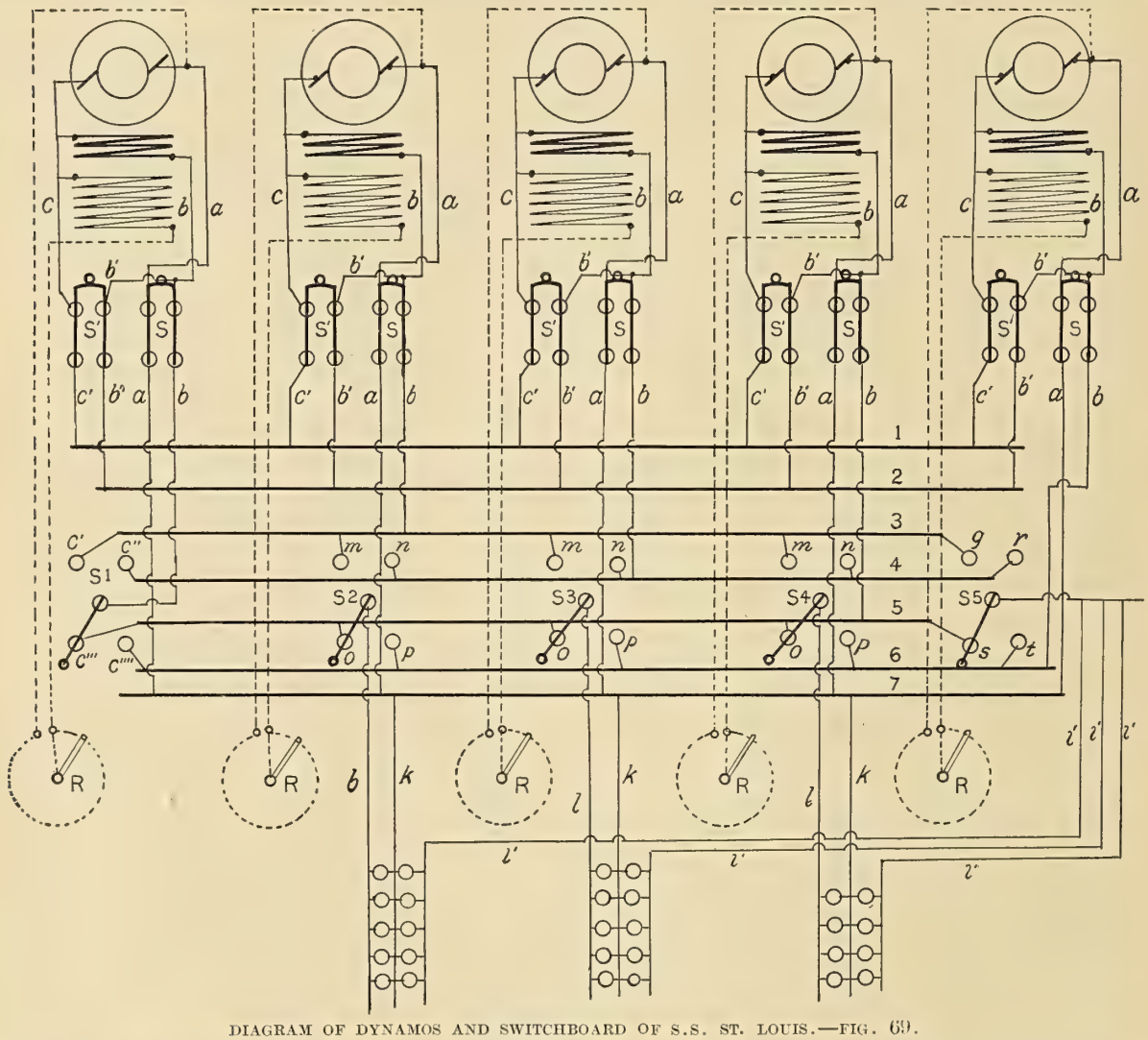


DIAGRAM OF DYNAMOS AND SWITCHBOARD OF S.S. ST. LOUIS.—FIG. 69.

amount of current, and this difficulty can be corrected at once by cutting out a small amount of the rheostat resistance. The arrangement does not render it possible to effect a perfect adjustment of the voltage, before the generator is thrown into service, but prevents its connection when the E. M. F. is so low that the current would be reversed. A little reflection will show that if the series coils are put in circuit before the armature is connected, the current developed by the latter, cannot at the most be reduced to zero, it will surely be something more than that, and will thus only require a slight adjustment of the regulating rheostat *R* to bring it up to the proper strength.

The reserve generator by being connected with switch *S1*, can be made to take the place of any one of the active machines, for, as will be noticed, the contacts of this switch connect with the buses *3*, *4*, *5* and *6*, to which the wires of these generators connect. Suppose for example that generator *No. 2*, counting from the right hand side, is to be replaced by the reserve machine, then after it is cut out, and the reserve machine has been brought up to the proper voltage, by connecting it with buses *1* and *2* through its *S'* switch, the handle of switch *S1* is turned so as to rest upon contact *c'''*. If now switch *S* of the reserve generator is closed, the *b* wire will be connected through the center contact and contact *c'''* of switch *S1* with bus *5* which is the one with which the *b* wire of generator *No. 2* is connected.

As the lever switch *S1*, can be moved so as to cover any one of the four outside contacts, and as these connect individually with the buses *3*, *4*, *5* and *6*, it is clear that the idle generator can be made to take the place of any one of the active machines, in just the same manner as explained above in connection with generator *No. 2*.

The external distribution circuits through which the current is conveyed to the lamps and motors are so arranged that they can be transferred from one generator to any other. In the diagram only three of these circuits are shown, for the sake of simplicity, but in reality there are about twenty. One of the wires of each of the external circuits, that marked *l'*, connects with the centre contact of switch *S5*, the wires marked *l* connect each one with an independent switch as shown at *S2*, *S3*, *S4*. These switches are constructed upon the same principles as *S1*, so that by moving the handle so as to cover any one of the four surrounding contacts, the wire *l* can be connected with the particular bus with which this contact connects. In the diagram, all the switches, *S2*, *S3*, *S4* are set so as to connect the *l* wires with bus *5*.

The wires *l* and *l'* connect through the lamps or motors with wire *k* and thus with bus *7*, which, as already explained, connects with the wires of the generators. By means of this arrangement it becomes possible to shut off, from the switch board, a portion of the lights in all the circuits or in any one circuit, as may be desired. To cut out a portion of the lights in all the circuits, the switch *S5* is opened, thus breaking connection between the *l'* wires and bus *5*. The individual circuits can be turned off by opening the other switches, thus opening switch *S3* would cut out the lights between wires *l* and *k* in the center circuit. The *l'* wires can be connected with any bus by simply turning switch *S5*.

From the foregoing explanation of this switch board it will be seen that it is very complete and that it facilitates the shifting of the load from one machine to any other or from one circuit to another to the greatest extent. The idle machine can be substituted for any of the active machines, any machine can be connected with any or all of the external circuits, and in fact every combination necessary can be effected. In the diagram the circuit breakers and the volt and ammeters are not shown, but from the explanations of their location in the circuit, given in connection with other diagrams, the manner in which they should be disposed can be readily understood.

ENGINEERS' DICTIONARY—XIII.

Dead-Water.—The water in the bottom of a Scotch boiler being removed from the direct application of heat tends to remain constantly at a lower temperature than the water about the tubes and furnaces. The former does not, therefore, readily join in the circulation within the boiler, but tends to remain fixed in location at the bottom of the shell. It is on this acount sometimes known as *dead-water*. The same term is also applied to the water following a vessel with full stern. As well known, it consists of eddies and whirls, rather than of smooth stream line flow, as in the case of a vessel with finer run and better form.

Disc Area *of Propeller.*—The area of the circle swept by the tips of the blades. The actual surface of the blades is usually related to the disc area, the ratio ranging from .20 to .50 with propellers of different forms and for different kinds of service.

Disc Crank.—A crank in which the *throw* or *web* consists of a circular plate or wheel with the shaft in the center, and the crank near the circumference.

Disc Valve.—In some cases the valve is of rubber or other flexible material, and is controlled by a guard secured in place over it as in Fig. 46. In other cases the valve is of metal or other non-flexible material,

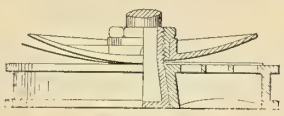


FIG. 46.

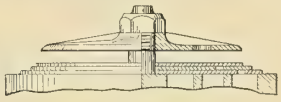


FIG. 47.

and is controlled in its lift by a stop or guard carried on the central stud on which the valve rises and falls. See Fig. 47. A low spiral spring is also usually added to insure quickness of closure. The valves shown are a patented type.

Discharge *Cock—Valve—Pipe—etc.* See *Delivery.*

Dog.—A bar or girder for securing a man-hole plate in place on a boiler. The stud or bolt of the plate passes through the dog and is secured by a nut which draws the plate hard and fast against its seat. See

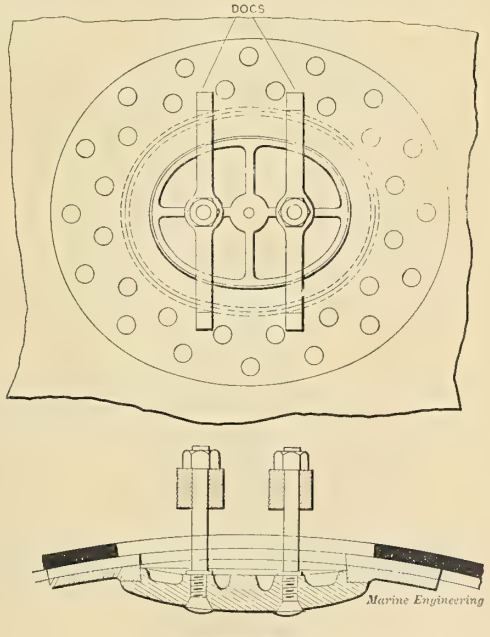


FIG. 48.

Fig. 48, showing the upper part of a Scotch boiler shell with the man-hole plate secured in this manner by two dogs.

Dome or *Steam-Dome.*—An extension or additional space on top of a boiler to give more steam room and to provide a place from which comparatively dry steam may be taken. A steam dome is commonly provided on locomotive boilers and in other cases where the steam room is limited in amount or restricted in height. In the "*Leg*" boiler (see under **Boiler,** Fig. 7) the steam dome takes the form of the so called *steam chimney.* As shown in the figure this is a space surrounding the base of the funnel. As the waste gases pass upward inside the funnel they give over a part of their heat to the steam which is thus dried to a greater or less degree, or even in some cases slightly superheated. In the ordinary Scotch boiler (see under **Boiler,** Fig. 6), a steam dome is rarely needed and but seldom met with.

Donkey Engine, *Boiler, Pump, etc.*—Terms signifying an engine, a boiler, a pump, etc., used for miscellaneous and auxiliary purposes. Thus the donkey boiler is a small boiler used when in port or at other times for operating auxiliary machinery such as deck winches, steering-gear, anchor-hoist, electric lighting machinery, pumps, or for heating ship, etc.

Double Acting Engine, *Pump, etc.*—In the usual type of steam engine, steam is admitted to, and acts alternately upon, both sides of the piston. Similarly in the usual type of independent pump, water is admitted to and discharged from each side of the piston alternately. Such an engine or pump is said to be *double acting.* In the *single acting* engine or pump the action is on one side or stroke of the piston only, as in most forms of gas engines, or in the ordinary air-pump (see under that head), or in the plunger form of feed pump.

Doubling Plate or *Reinforce Plate.*—A plate used to stiffen or strengthen the metal of a boiler shell, or other like structure, in the vicinity of a man-hole

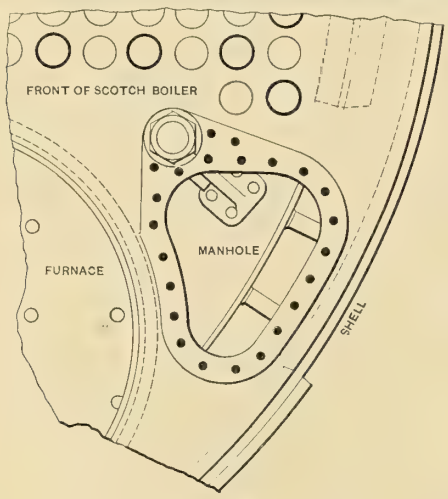


FIG. 49.

or where for other reasons, greater stiffness is desired. It consists simply of a plate riveted to the shell as in Fig. 49, showing the reinforce plate around a boiler man-hole.

Down Comer, *Down Cast Pipe,* or *Down Flow Pipe.*—A pipe in a water-tube boiler for returning the water from the upper drum to the lower drum or feeder for the tubes. It is much larger in size than the steam forming tubes, and is situated usually outside the boiler shell, or in any event is shielded from the direct action of the hot gases. See also under **Boiler**—*water tube.*

Draft.—A term referring to the difference between the pressures of the air in the ash-pit and the gas in the base of the funnel, and hence to the pressure which tends to force the air through the fire and maintain the combustion. Good draft implies a considerable difference of pressure, large quantities of air forced through the fire, and good combustion. Poor draft on the other hand implies but little difference of pressure, small quantities of air forced through the fire, and poor combustion.

Draft Gauge.—See *Air Gauge.*

Drain Cock—*Valve Pipe.*—A cock, valve or pipe for the purpose of allowing and regulating the removal of water from a cylinder, a steam pipe, or other closed space.

Drain Gear.—A term referring in general to a drain cock, valve or pipe, or to any of the rods, levers, handles, etc., which may be provided for operating them.

Drift-Pin.—A tapering steel pin formerly used in boiler making in order to enlarge and bring together rivet holes which do not come quite fair in overlapping sheets. The use of the drift pin results in the stretching and deformation of the metal around each hole, and its elongation into a more or less oval form. These are often very imperfectly filled by the rivet. In modern practice with drilled holes carefully laid out there should be no need for the drift-pin, and in most specifications its use is strictly forbidden.

Drip-Cock—*Valve Pipe.*—See *Drain Cock, etc.*

Drum.—A general name given to a hollow cylindrical chamber, as for example the steam and water *drums* of a water-tube boiler, see **Boiler,** Figs. 8 to 11. In certain forms of boilers, also, the steam dome takes the form of a relatively small horizontal cylinder or drum lying over the main boilers and connected to them by two or more short lengths of pipe known as *goose necks.*

Dry-Pipe.—A pipe in the upper part of a boiler for collecting the steam and for effecting at least a partial separation of the water from the vapor. As fitted in modern practice the dry-pipe consists of a pipe running the length of the boiler, closed at the end, and provided on top with a large number of small slits or holes. In the aggregate the cross-sectional area of these openings is about the same as that of the pipe. The upper surface of the pipe thus fitted acts somewhat as a strainer, and prevents the inflow of water in bulk in case a large mass should in any manner find its way into the steam space in the top of the boiler.

Dry Steam.—Steam which does not contain liquid water in suspension. Dry steam is transparent and colorless as the air. Witness for example the space above the water in a gauge glass. Steam escaping into the air is rendered visible by a more or less complete condensation into fine particles of water. Such steam, or vapor mixed with water in this condition, is said to be *moist* or *wet.* Steam as provided by the ordinary boiler has usually in suspension an amount of water varying from, perhaps, three or four per cent. down to nothing. The quality of steam refers to the proportion which is vapor. Thus a quality of 98 per cent means 98 per cent vapor and 2 per cent water. Dry steam would have a quality of 100 per cent.

Dynamometer.—The word means literally *force measure.* It is also used in the sense of *work* or *power measure.* As a force measurer the dynamometer may be represented by the common spring balance for weighing. When such a spring balance or some equivalent device is used for measuring the pull or push or twist between two parts of a machine or between a moving body and some other body pulled or pushed or turned by it, the arrangement is usually called a *transmission dynamometer.* The force transmitted being thus measured and the speed of transmission being known or measured, the work and power transmitted can be directly found by

multiplying the one by the other. In the *absorption* dynamometer the *torque* or twisting moment of the engine shaft is measured, and this together with the revolutions furnishes the necesstry data for computing the work. The latter instead of being transmitted on, as in the *transmission* dynamometer, is absorbed by the apparatus and transformed into heat. The most common form of absorption dynamometer is the Prony brake in some one of its many forms. A typical arrangement is illustrated in

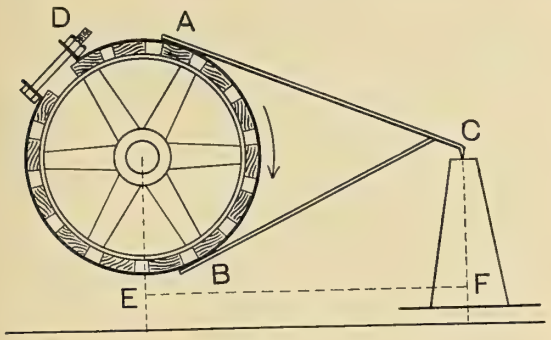


FIG. 50.

Fig. 50. The brake is this case consists of a number of blocks of wood carried by a sheet metal band and provided with arms A C and B C. This is placed on a brake wheel driven by the engine whose power is to be measured. The nut *D* provides for adjusting the tension of the brake on the wheel. The strut *C F* rests on a platform scale or other means of measuring the force required to keep the brake from turning around with the wheel. By means of the nut the tension is adjusted as nearly as possible so as to keep the beam of the scale floating, thus indicating a constant force at such value as is shown by the beam poise. Let *P* denote the value of this force, *a* the arm *E F* and *N* the revolutions. Then the work absorbed is given by the formula:

Work = 6.2832 *P a N*.

Ebullition.—The act of boiling. When water boils or is in *ebullition*, vapor is formed in globules at the heating surface. These rise to the surface of the water and there escape, thus causing the violent agitation of the liquid which is characteristic of this condition.

It Is Reported

That the great floating dry dock at Havana will not be turned over to the United States, but will be put up at auction by the Spanish Government. It was built in England and cost about $650,000.

That the first torpedo boat destroyer of the Navy to be sent on her trial, the Farragut, reached a speed of 30.1 knots on her final trial at San Francisco. She was built by the Union Iron Works.

That the Manhattan Dry Dock & Construction Co., incorporated under the laws of West Virginia with a capital of $5,000,000, will establish a shipyard in New York harbor. The articles of incorporation give the company the right to "build, repair, sell and operate ships, vessels, etc."

That representatives of Vickers, Sons & Maxim, of England, have looked over the Newport News shipyard, and reported in favor of the purchase of a large interest in it by the English concern, with the intention of adding to it a modern gun factory. As is well known this English concern is one of the most prominent manufacturers of modern weapons in the world.

CORRESPONDENCE.

[Communications on matters of interest to marine engineers, for insertion in the correspondence department, are solicited. These, wherever possible, should be supplemented by rough sketches or drawings, which will be reproduced if necessary to illustrate the subject, without cost to the writer.

Full names and addresses should be given, but publication o these will be withheld where requested.

We do not assume responsibility for the opinions expressed b correspondents.]

Efficiency of Naval Engineers.

Editor of Marine Engineering:

In the report which appears in the columns of your December issue of the recent meeting of the Society of Naval Architects and Marine Engineers, I note the following statement:

"We have only very few officers of the Engineer Corps competent to give experienced trained engineering supervision to those repairs on torpedo boats which are attempted at navy yards, and those few are rarely available for duty."

This is a grave charge against the efficiency of an important branch of our navy, for, if naval engineering officers are not competent to supervise such repairs to torpedo boats as are considered to be possible to attempt at navy yards, it is surely high time, in view of the frequent mishaps to which torpedo boat machinery appears to be subject, for the navy to set about securing officers who do possess the necessary professional qualifications. Moreover, the bearing of the charge is not limited to the specification cited, for those not sufficiently competent to supervise repairs to torpedo boat machinery are hardly a class of men to whom to trust supervision over the repair of the complicated and often delicate machinery met with in modern warships in general.

As the charge quoted is made in a paper presented before a national professional body, and is under the name of a naval officer of high rank, who, moreover, I note is referred to in the discussion as the commander of the torpedo flotilla during the late war, it would appear that the Navy Department should take cognizance of it.

Personally, I do not believe that the statement in question is warranted, for it belies the efficiency which the corps of naval engineers displayed during the late war when serving in the fleet or in repair ships, which efficiency is a matter of official record and, it may be added, of congratulation to the American engineering profession in general. Nevertheless, in view of the publicity given to the charge and the implication of general incompetency that it carries with it, and in view also of the rank and the late service of the officer responsible for the statement, the Washington naval authorities would seem to be called upon to investigate it in the interest of the country in order that the necessary measures may be taken if it be proved well founded; and in fairness to the personnel of the naval engineering corps that they may, in the contrary case, be relieved of the suspicion to which the charge gives rise concerning their professional competency in general.

MEMBER SOC. N. A. & M. E.

The dispute between the Government and the contractors for the new monitors, referred to in our December issue, has been settled by the decision to let the single turret design stand, only increasing the vessels in length by 27 ft. and the displacement by about 500 tons. The original contract price will be increased by about $100,000 in each case. The amended design will give vessels of 3,235 tons displacement. They will have a maximum speed of 11 1-2 knots and total capacity for 400 tons of coal.

QUERIES AND ANSWERS.

Communications intended for this department will not receive attention unless accompanied by the full name and address of the sender, which will be considered confidential.)

Q.—Have compounds used in boilers to prevent scale any effect on the steel or iron? J. A. C.

A.—This depends altogether on what is used. There are many compounds which are quite safe and others which tend more or less actively to corrode the plates, tubes and braces of the boiler. Some compounds contain tannic acid which attacks iron and steel strongly, and others contain a variety of substances more or less liable to corrode or attack the boiler, especially if used too freely.

A very good plan is to take a pail full of water containing the compound in proportion somewhat stronger than as used in the boiler in order to increase the effect. Then boil this and put into it a piece of boiler plate or like material and watch for a few days, or even for two or three weeks, weighing the plate from time to time to note the loss, if any. Still more rapidly the probable effect may be arrived at by using a piece of well polished steel and watching carefully from day to day any signs of discoloration or corrosion on the surface. If the surface becomes rusted or blackened in marked degree, or pitted, it will be safe to avoid the use of the compound which produced this effect.

Q.—We have been discussing why a steel ship floats and can't agree. I've seen a water-logged lumber schooner which had been floating for days, and I reckon a steel ship with as much water in her would go down quickly. * * * * * * Why doesn't a big battleship with so much weight go to the bottom instead of floating? KEY WEST.

A.—To answer your question let us first understand clearly that a ship floats for the same reason that a cork or a pine stick does. This does not tell us much, to be sure, but it is an advantage to be able to see clearly at the start that the flotation of all bodies has one common cause and one common explanation. This explanation cannot be given completely, however, without introducing a mathematical discussion based on the properties of liquids, and such a mode of treatment would not be in place in this discussion of the subject. As the next best thing, then, we must admit the following principle, which may be shown experimentally to be true in all cases:

A body wholly or partly immersed in a liquid is pressed or buoyed upward by a force equal in amount to the weight of the liquid displaced.

By the liquid displaced is meant a volume of liquid equal to the volume of the body, if wholly immersed, or to that part of the body below the water surface if partly immersed.

Suppose, then, that we start in with a solid block of steel 12 in. by 12 in. on the base and 18 in. high, supported by a rope from a convenient point, and allowed to sink in sea water to an immersion of 12 in. The displacement would be just one cubic foot, and the weight of this volume of sea water 64 pounds. The weight of the steel would be about 720 pounds. Hence, we have a pull downward of 720 and a push upward of 64, and hence a net pull on the rope of 656 pounds. Suppose now that without disturbing the block we imagine it scooped out on top. We need not be concerned as to the means of doing this, but simply suppose the material removed and the block thus made more or less hollow with sides and bottom left untouched. Suppose in this way 100 pounds were removed. The weight would then be 620 pounds. The displaced water, however, would remain unchanged in amount, and the upward force of 64 pounds act as before. Hence, the net pull on the rope would now be reduced to 556 pounds. Continuing in this way we may suppose finally 656 pounds of steel removed, leaving a hollow steel box with relatively thin sides, and weighing 64 pounds. The depth of immersion and the amount of displaced water would remain the same, and the upward or buoyant force would still be 64 pounds, and therefore just sufficient to balance the weight and reduce the pull on the rope to nothing. The rope having nothing to support could now be removed and the box would float freely in this condition. Why? Because the weight downward was just balanced by the buoyancy or pressure upward.

Suppose we kept on and removed more steel amounting to, say, 14 pounds. The box would then weigh 50 pounds, while at the immersion of 12 in. it would still experience an upward push of 64 pounds. There would hence be in this condition a net upward push of 14 pounds, in answer to which the box would rise, thus decreasing the amount of displaced water. This would continue until the upward push became reduced to 50 pounds, the equal of the downward weight. This would occur at an immersion of 9 3-8 in. (in this particular case), in which condition the box would float freely. On the other hand, suppose some of the chips were thrown back, bringing the total weight up to 80 pounds. In answer to the excess of force downward the box would settle in the water until the weight was again balanced by the increased buoyancy. For 80 pounds this would occur at 15 in. immersion. Thus the box would rise and fall according to the weight carried, but in each case when floating freely the buoyancy upward would just equal the weight downward.

Now, suppose a hole drilled in the bottom of the box. Water will flow in. Such an inflow may be looked on either as a loss in buoyancy or as an increase in cargo. For our present purposes the latter is the simpler. Suppose, then, that the water flows in until it is 3 in. deep over the bottom of the box and the hole is then plugged. What happens? The weight of water introduced is about 14.7 pounds, and the total weight, box and water cargo, is 78.7 pounds. It, therefore, settles as before until the immersion is such that the total displacement gives an equal buoyancy of 78.7 pounds, which will occur at a draft of about 15 in. If, instead of plugging the hole the water is allowed to run in, the box will continue to sink deeper and deeper in the endeavor to gain more buoyancy. By the time the water is about 6 1-2 in. deep inside, the top of the box will be brought to the level of the water outside, no additional buoyancy can be gained, and if the top is open the box will suddenly fill and sink. Why? For the same reason that any lump of steel would sink, because the weight is greater than the buoyancy, or the weight of the steel is greater than that of an equal bulk of water. If a thin water-tight deck or cover had been fitted over the top, the filling would still proceed through the hole, and the box sink none the less, and for the same reason as before.

In further illustration of the same principles, suppose we have a solid lump of wrought iron. We throw it into water, and it sinks. We beat it out into a thin sheet, and it sinks just the same. We next cup the sheet and so form a shallow dish or bowl. It now floats. Why? There is the same amount of material as before. Simply because in the last case we had so formed the body that the water it could displace was far greater than its own volume—many times greater, in fact. As a lump or as a plane sheet, it could only displace water corresponding to its own volume. In the form of a bowl it could displace in addition the inside volume, and this great increase of displacement meant an additional buoyancy which enabled it to float and even to carry a load. Pierce the bottom of the bowl, water flows in, and the bowl sinks because now it can only displace, even when down to the water's edge, a volume of water equal to the volume of the material—the same as when in the condition of a flat plate. In the same way the plates, angles, beams, etc., going to form a steel ship would all sink if thrown individually into the water, but if they are so disposed as to form a ship, which is after all a kind of cup or bowl, the water which can be displaced is enormously increased, and the ship floats and carries her cargo as well. Knock a hole in the bottom, water flows in, buoyancy is lost. and if the compartment is large or is not water tight, the ship fills and sinks in the same way and for the same reason as in the case of the bowl.

Q.—Can you give me information in regard to the Civil Service examinations for admission to the Government service as Naval Architect? C. H. G.

A.—The naval constructors in the Government service are graduates of Annapolis, but qualified persons from civil life are employed by the Bureau of Construction and Repair of the Navy Department as draftsmen, assistant draftsmen and tracers, after having passed the Civil Service xaminations Applicants are required to file with the Civil Service Commission at Washington, on a special form, certificates from their present employers or instructions "testifying to their

skill and adaptability." For draftsmen, the examination extends over four days, and includes these subjects: Letter Writing; Applied Mechanics; Ship Calculations; Practical Shipbuilding; Ship Drafting. For assistant draftsmen three days are allowed, and the same subjects are required as for draftsmen with the addition of Arithmetic. Less percentages are necessary, however, in some of the subjects, and generally the questions are not so difficult. For the position of tracer, a two-day examination is given and the requirements are: Penmanship; Letter-Writing; Arithmetic; Tracing Ship Drawing; Free Hand Lettering. In some of the subjects the questions following the practice of the Navy rather than the mercantile marine. The salaries of the positions are, approximately: Draftsmen, $1,550 to $2,000 per annum; Assistant Draftsmen, $1,250 to $1,550 per annum, and Tracers, $1,000 to $1,250 per annum. You can get more detailed information about these examinations by addressing the United States Civil Service Commission, Washington, D. C.

Recent Legal Opinions in U. S. Courts.

We have before us a number of recent opinions delivered by judges of the Federal courts, and from them have made a selection of several which contain points of special interest for those engaged in marine work. We have disregarded the merely legal technicalities in each, confining the reports to the points here referred to.

NAME PLATE FOR BOILER.

Suit was brought by H. M. Sciple and others in the District Court of New Jersey to recover the balance due on the purchase price of a boiler built for the steamer Otha J. Sample. The contract called for one vertical marine boiler of certain dimensions subject to the tests and regulations prescribed by Federal law. The boiler was to pass the U. S. inspection for 125 lbs. of steam, working pressure, and to be complete, with grates, waterpan and hood. There was a dispute regarding an allowance to be made for this hood, which was not supplied, and a claim also by the purchaser of the boiler, one Sample, for an allowance because the makers failed to furnish with the boiler a "name plate" showing the name of the maker, the place where manufactured, and the tensile strength. After listening to the evidence, Judge Kirkpatrick found that in every respect that which was furnished complied with the requirements of the contract, the hood specified being omitted only by agreement. Then quoting the 4431st section of the revised statues which requires "that every plate of boiler iron or steel made for use in the construction of steamboat boilers shall be so stamped in such places that the marks shall be left visible when such plates are worked into boilers," the Court held there was not any statutory requirement for a "name plate" such as the defendant had demanded, nor was it called for in the contract. Consequently he gave the parties who furnished the boiler judgment for the amount claimed.

LIENS FOR ENGINEERS' WAGES.

A very interesting decision defining the rights of employees of a dredging company to establish liens for wages due was made by District Judge Hanford in the State of Washington. The Bowers Dredging Co., an insolvent corporation, was in the hands of a receiver and under the jurisdiction of the U. S. Court. Certain engineers, firemen and deck hands sought to intervene, claiming to have maritime liens upon the dredges of the company for wages due and unpaid. The company had operated two hydraulic dredges in the harbor of Seattle under a subcontract from a harbor improvement company which had a contract with the State. Discussing the rights of the employees who intervened the Court says:

"The main question in the case is whether the dredgers are vessels subject to admiralty process, whether the work which they were doing was a maritime service, whether the contracts under which they were supplied and kept in repair are maritime, and whether their crews have maritime liens for their wages. The writers and judges who have expounded maritime laws, and the rules by which the jurisdiction of admiralty courts must be measured, have not succeeded in making known any satisfactory test by which floating structures which are subjects of admiralty jurisdiction, and to which maritime liens may attach, may be distinguished from those which have no place in the realm of maritime jurisprudence. There are numerous decisions which tell that adaptability to float on the water, masts, sails, propelling machinery, steering apparatus, capacity for carrying merchandise or passengers, and mobility, are features by which a subject of admiralty jurisdiction may be recognized; but the decisions are not all consistent with any guiding principle which makes admiralty jurisdiction depend upon the size or shape of a vessel, her means of propulsion, or her adaptability for use. According to the decisions, a ship, although afloat, is not a ship if her original construction, rigging, and furnishing remain incompleted. Men employed on board of a vessel for her preservation do not acquire maritime liens for their wages if she is out of commission; that is, if she has no voyage in contemplation. A ship is not employed in a maritime service when used merely as a warehouse to hold her cargo after the completion of a voyage, and while navigation is suspended. The actual employment of a structure designed for use in the transportation of merchandise or passengers by sea is not under all circumstances conclusive. Wharves and warehouses are necessary for the transportation and preservation of merchandise to be carried in ships to a distance, and yet such structures, although in fact instruments of commerce and aids to navigation, are not maritime vessels. Floating dry docks, used in the repair of vessels, are not maritime things. On the other hand, a private yacht or pleasure boat, not designed for nor employed in trade or commerce, is a vessel which may be a subject of admiralty jurisdiction. The width of a stream or the length of a voyage is no criterion by which to determine the character of the service, nor the question of admiralty jurisdiction. Neither will jurisdiction of a floating structure be denied by a court of admiralty because it does not carry masts, propelling machinery, or steering apparatus, or lacks accommodations for a crew. There is great confusion in the decisions as to whether particular structures, such as pile drivers, wharf boats, rafts, and dismantled vessels, are to be classed within or without the pale of admiralty jurisdiction."

Then follows a list of cases in which jurisdiction was sustained over a great variety of floating structures, including a floating elevator; a harbor tug of less than five tons; a scow; a canal boat used only upon an artificial canal wholly within one state; a barge without masts, sails, propelling machinery, rudder or anchor; a ferryboat; a steam derrick boat; a floating boathouse; a floating bath house; a pile driver; a dredge, and a raft of timber. After citing these cases the Court continues:

"A dredging vessel designed to facilitate navigation, by going from place to place, to be used in deepening harbors and channels, and removing obstructions from navigable rivers, and to bear afloat heavy machinery and appliances for use in that class of work, may commit, or be injured by, a marine tort, and she may become subject to a maritime lien for salvage. She has mobility, and her element is the water. She can be used afloat, and not otherwise. She has carrying capacity, and her employment has direct reference to commerce and navigation. I perceive no reason for exempting such a vessel from the liabilities arising from non-payment of the wages of her crew, or from such unfulfilled contracts as would subject other vessels to liens enforceable by a court of

admiralty. I find no difficulty in pronouncing in favor of the engineers, firemen, deck hands and captains who worked on board of the dredgers. They have maritime liens for the balances due to them for wages. The captains were not clothed with the authority of masters, but were simply foremen in charge of the working crews. Therefore, the rule that the master of a vessel has no lien for wages does not apply to them. Those who worked as general mechanics in keping the machinery in repair, and the pipe men, who attended to laying, connecting, and moving the lines of pipe, and those who performed necessary labor upon and about the filled area, are also entitled to liens. Their services were required in prosecution of the enterprise in which the vessels were employed. The right to claim a lien for wages under the general maritime law is not restricted to favor only mariners who serve the ship with peculiar nautical skill, but extends to all whose services are in furtherance of the main object of the enterprise in which the ship is engaged."

A decree was accordingly entered directing the sale of the dredges and allowing as preferred claims the amount due the employes for wages.

CONTRACT TICKET CLAUSES.

A point made in a personal injury suit by District Judge Brown in New York is worth noting. Jacob Moses, a four-year-old boy, was a steerage passenger on the Hamburg Line steamship Persia, and in a collision between that ship and another he suffered such injuries to his right hand that it had to be amputated. A clause in his contract ticket limited responsibility of the ship and owners to $100 in case of loss or injury to the passenger arising from steam, latent defects of the steamer, negligence of the company's employees or from negligence in navigation of any other vessel. Referring to this the Court said that had the contract provision been a reasonable one it would have been sustained, but considering the nature of the injuries liable to happen to any passenger through careless navigation (as in this case) including possibly loss of life or limb, and the large awards often made therefore, it seemed to him that the stipulation that the damages for any possible injury should not exceed $100 could not be seriously considered as any reasonable or substantial provision. The sum of $100 was scarcely more than a nominal sum. Considering the occupation of the boy's father and the probable business chances for the boy when grown up, the Court made an allowance of $2,500 to the son and $500 to the father with costs.

A 100 ton floating derrick is to be constructed for use at the New York Navy Yard for the purpose of handling armor plates, ordnance and other heavy material. It will be operated by steam.

In his report Assistant Secretary of the Navy Charles H. Allen calls attention to the unsuitability of wood as a material for dry docks. He says that the wooden dock No. 2 at the Brooklyn Navy Yard is rotting away like the one at Norfolk.

An order for two transatlantic liners, each 560 ft. in length, has been placed at the Clydebank Works in Scotland by the International Navigation Co. The steamships Paris and New York of the Southampton service of this company were built at Clydebank. The new vessels will be put on the Antwerp-New York route flying the Red Star flag.

Arrangements are being made by the Navy Department for the establishment of a naval station at Honolulu, equipped with wharves, cranes, store houses, etc. Land for this purpose has been set aside by authority of the President. Contracts have also been let for the construction of proper coaling facilities on United States property at Pago Pago, Samoa.

RECENT PUBLICATIONS.

THE THETA-PHI DIAGRAM *Practically applied to Steam, Gas Oil, and Air Engines.* By Henry A. Golding, A. M. I. M. E. The Technical Publishing Co., Manchester, England. First Edition, 1898. Size 5 by 7 1-2. Pages, 123. With numerous diagrams. Cloth, 3s.

According to the author's preface the purpose in this book has been to present in as simple and practical a manner as possible the use of the temperature-entropy diagram, and the various methods of drawing it for different heat motors. In the preparation of the book the author has made use of the work of Gray, Boulvin, Williams, Sankey and others in the field, and due acknowledgments are made of indebtedness to these sources. The book is divided into six chapters treating of Entropy, Entropy of Water and Steam, Conversion of Indicator Diagram to Entropy Diagram, Heat Losses, Application to the Gas Engine, Application to Oil and Air Engines. In the first two chapters the fundamental explanations relating to entropy and temperature-entropy diagrams are given, usually in plain and simple form, though of necessity some acquaintance with higher mathematics is assumed. In Chapter III on the conversion of the indicator diagram into the temperature-entropy curve, the treatment is less satisfactory. Some inaccuracies in the details of the mode of procedure seem to have crept in, due perhaps to haste in preparation, but of still more importance, from the standpoint of the principles involved, is the question as to whether the basis of the method is well founded. The author, in common with others whom he has followed in this matter, considers the temperature-entropy diagram as the temperature-entropy history of a certain space or volume instead of the temperature-entropy history of a certain quantity of steam or steam and water. The indicator card is a pressure-volume history of the volume inside the cylinder and its area gives the external work done. If, however, the temperature-entropy diagram is to have definite significance as a diagram showing heat exchanges, it must relate throughout to a constant quantity of the substance. The heat involved in any thermal change in a substance of constant weight Q is $H = Q \int T\, d\phi$. If, however, Q is a variable we must put $H = \int Q_T\, d\Phi$. In the latter case the heat H cannot be represented by an area on the temperature-entropy chart, prepared as it is for 1 lb. of the substance. If the cycle as a whole consists of a series of stops during each of which the quantity involved is constant, then each may be dealt with separately, but their combination into a continuous diagram on the temperature-entropy chart is without definite meaning. The same general objection lies against the application of the method to the various cards individually of a multiple expansion engine. The quantity involved changes many times throughout the various cycles, and the entering charge of working steam is broken up and resubdivided on its way through the engine until its identity is entirely lost. A closed diagram in such case means therefore a *series* of temperature-entropy histories in which the quantity differs from one to another, and therefore in which the area of the diagram does not correctly represent the heat transformed into external work. It is not denied that diagrams derived in this way correspond in area fairly well with the indicator cards to which they correspond, the one being measured in the heat and the other in mechanical units. The differences in any event are small, but it is the principles involved which are called in question, rather than the amount of error resulting. In the fourth chapter the influence of jackets, of superheaters, and of heat losses and variations from the

ideal cycle are considered. In connection with these subjects it would have been well to bring into greater prominence the fact that the temperature-entropy diagram is limited to reversible processes. Remembering this and that the actual cycle is full of irreversible features, it is evident that the use of the temperature-entropy diagram involves a considerable element of uncertainty, and any specially close agreement between its area and that of the indicator card can be only accidental in character. In the last two chapters, gas oil and air engines are considered, using the general principles established in the first part of the book. The treatment is simple and perhaps as satisfactory as can be expected from the nature of the subject. Sufficient notice is not given to the fact that here, too, we are dealing largely with irreversible processes, and furthermore that in the gas and oil engine the working substance is a complex mixture of gases changing in character during the stroke and with varying thermal properties. The use of a mean specific heat, and of values of entropy based on it, can be at best but an approximation, but still perhaps the best that can be made under the circumstances. For a more detailed mode of treatment reference may be made to a recent paper by *Stodola* published in the "Zeitschrift des Vereins Deutscher Ingenieure" September 17, 1898. The book closes with a table of the weight of dry saturated steam carried out to tenths of a pound, with difference for hundredths. This will be a great convenience to all who are interested in computations relating to the general subject of steam-engine performance and economy.

"An American Cruiser in the East," by Chief Engineer John D. Ford, U. S. N., is now in its second edition, though but recently issued from the press of A. S. Barnes & Co., 156 Fifth Ave., New York. In view of the acquisition of the Philippines this book is doubly interesting, though aside from its peculiar value in this respect it is a most interesting work, taking the reader through Japan, China and the Philippines as though he had set out on the journey himself. In the scond edition there is an appendix containing a vivid description of the sea fight at Manila, and the events which led up to it. Mr. Ford served on the U. S. S. Baltimore in this eventful action. His descriptions of Japanese and Chinese manners and customs are very complete, and there is a profusion of fine engravings to entertain the eye as the text enlightens the mind. The author is an earnest champion of the policy of expansion. Referring to the natives he says: "They have always wanted liberty and have fought the Spaniards for it on many a hotly contested field since 1522." As to the future he writes: "These people need steamships of from 100 to 500 tons to trade amongst the islands; they need steamships of from 3,000 to 5,000 tons to trade with the United States and other parts of the world; they need railways, locomotives and cars for internal traffic; and they need thin dress goods; all sorts of thin white goods, insertions and laces, black and white prints of thin cotton, silk and woolen goods, thin-woven and knit goods, fancy and staple hardware, tinware, groceries, canned goods and flour, steam engines, pumps, sugar mills, agricultural implements, furniture, books and stationery, and our public school system. They can pay for these with sugar, tobacco, hemp, camphor, rice (which are produced in great quantities, coal, gold and many varieties of beautiful hard woods. Why should our people not have this trade?" The book is finely printed on a good paper, and artistically bound in cloth it costs $2.50.

The Spanish war and its consequences has given great prominence to questions of national defence and foreign policy which have hitherto not received general attention. That the course of events has been foreshadowed by those who have devoted study to such matters is evidenced by the collection of essays written by Captain A. T. Mahan, U. S. N., now published under the title of "The Interest of America in Sea Power," by Little, Brown & Co., of Boston. This work is a collection in book form of several detached papers written for leading literary publications by the distinguished author. They are severally entitled: "The United States Looking Outward," "Hawaii and Our Future Sea Power," "The Isthmus and Sea Power," "Possibilities of an Anglo-American Reunion," "The Future in Relation to American Naval Power," "Preparedness for Naval War," "A Twentieth-Century Outlook," and "Strategic Features of the Caribbean Sea and the Gulf of Mexico." Through the courtesy of the original publishers of these papers they are now available for information and study in a compact form. For the many who appreciate the grave importance of the subjects treated, but who have been too busily engaged otherwise to undertake independent research and reflection, this work will be of great practical value and interest. Space does not permit of any extended notice of the several papers. It will, however, be apparent, considering the subjects and the known scholarly treatment of such by the author, that the work is one that will well repay earnest perusal. The book is of convenient size and is published at $2.00 bound in cloth.

The 1899 issue of the valuable Record of American and Foreign Shipping, New York, has been received. This very excellent index of classifications has been thoroughly revised and brought down to date, and also contains a large number of classifications not included in the 1898 bound issue, the additional pages numbering 129 in the alphabetical list of vessels. It is an invaluable book of reference for those who find it necessary to inquire into the characteristics of merchant vessels and their condition. The work of the Society has evidently been very carefully done, and no vessels are classed except such as have been submitted to survey according to the prescribed rules and the class approved by the Committee at New York. This classification society has made a change of name from the American Ship Masters' Association to the American Bureau of Shipping, which latter is more appropriate and explanatory of the purposes of the organization. The Record is published with the approval of the Boards of Marine Underwriters at New York, Boston and San Francisco. In the present issue the contents include the rules for the construction and classification of all styles of vessels, the Record proper giving the chief characteristics of ownership, etc., of vessels of all types both home and foreign; a convenient index to the compound names of vessels in the Record arranged alphabetically by the last name; also a list of vessel's names which have been changed, and valuable lists of owners, shipbuilders, etc. Though a minor detail the manner in which the Record is gotten up deserves mention for its excellence. In the arrangement of the matter, in printing, press work and binding, it is a remarkably fine specimen. The address of the Bureau is 37 William street, New York city.

Students of French who desire to profit by study of the many valuable works in that language on subjects related to marine engineering and architecture often meet with difficulty in comprehending technical words and phrases which the ordinary dictionary does not contain. For such the "Technical Dictionary of Sea Terms, Phrases and Words" in both languages, published by Crosby, Lockwood & Son, 7 Stationers' Hall Court, Ludgate Hill, London, is a most useful pocket book of reference. It is intended, indeed, for the use of "seamen, engineers, pilots, shipbuilders,

ship owners and others," and is the work of a thoroughly practical seaman, William Pirrie, late continental marine superintendent to the African Steamship Co. Besides the lists of single words there are translations of the various phrases used in the management of a ship both in the navigation and engineering departments. It is an up-to-date practical little book; brief yet sufficient.

The complete report of the Load Line Committee to the London Board of Trade upon the questions relative to the revision of the North Atlantic winter load-line, referred to its consideration, will be found in the New York Maritime Register of December 14, 1898. This is an important document to ship owners and others interested in over sea trade.

TRADE PUBLICATIONS.

Shipyard and other tools are thoroughly illustrated in a 9 by 12 catalogue designated as Catalogue P, just received from the Hilles & Jones Co., Wilmington, Del. Each machine is illustrated by a large half tone engraving nearly the full size of the page and the cover is printed in three colors. Every shipyard using tools for working plates, etc., should have a copy of this catalogue for permanent reference.

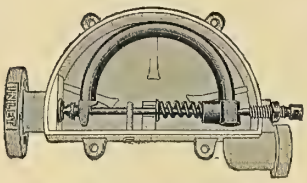
"The Argonaut, What she was Built for and What she has Accomplished," is the title to a very neatly printed 16-page booklet issued by the Lake Submarine Co., 11 Broadway, New York. A number of pictures are given of this unique boat showing her afloat and also performing submarine work in various ways. The purpose of the booklet is evidently to explain in considerable detail the possibilities from a business point of view of submarine investigations.

Graphite Paint.—Wm. Hooper, of Ticonderoga, N. Y., writing of the use of paints says: "If the surface to be painted is perfectly dry when finely ground graphite is applied, the paint will prove the most lasting paint known, because if time eliminates all of the oil, the graphite seems to adhere to the surface painted just the same as a piece of paper or wood will appear after it has been rubbed with a lead pencil or a piece of graphite. No other pigment known to me will remain on the surface painted after the oil has been thoroughly destroyed. With the experience I have had with graphite paint." Booklets regarding graphite paint can be had from the Joseph Dixon Crucible Co., Jersey City, N. J.

A half dozen of exceptionally handsome and valuable catalogues have been received from the Advertising Department of the Westinghouse Companies, Pittsburg, Pa., descriptive of the electrical apparatus manufactured by the Westinghouse Electric and Manufacturing Co. They are finely printed and give much statistical and other matter of value to the reader interested in electrical matters. One entitled "A Quarter Million Horse Power," describes in some detail the big electrical plant at Niagara Falls. Another is entitled "Electricity for Machine Driving," illustrating a variety of machines operated by Westinghouse motors. The third is devoted to lighting arresters, the fourth to alternating current arc lamps, the fifth to the modern roundhouse turn table, showing the application of electric motors to turn tables. The largest one of the six is Part 1, of Electric Street Railroad History. Among these catalogues must be several which would be of much value to anyone interested in electrical work, either in the shipyard or on board ship. Copies can be had upon application.

Hot Water

saved with the "Heintz" Steam Trap—puts it where you want it, too. Works in any position—opens and closes on difference of one degree of heat—211° to 212°—smallest size discharges one gallon water a minute and not an ounce of steam wasted. Six parts besides the case—No levers, no floats, no springs. Practically nothing to wear out. Ask for Booklet " G "



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136 South Fourth Street,
Philadelphia.

" The Heintz—the best—tho' it has imitators."

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REDUCING VALVES

to control or reduce steam, water or air pressures.

"MASON"

Valves have had a world-wide reputation for years.

Write for prices.

THE MASON REGULATOR CO.,
BOSTON, MASS.

A portable hydraulic punch is illustrated in two large 8 by 10 pictures in a folder issued by the Cornell Portable Hydraulic Punch Co., 922 North Nineteenth street, Philadelphia, Pa. The features of the punch are fully set forth in the circular.

Generating sets with automatic upright and horizontal engines manufactured by the B. F. Sturtevant Co., Jamaica Plain, Mass., are illustrated by large cuts and described concisely in a large 8-page folder issued as Bulletin G. Every man interested in such matters should have a copy of this bulletin, which can be had upon application. Bulletin E, issued by the Sturtevant Co., entitled "Draft without a Chimney" was in such demand that a second edition has been issued and is now ready for distribution.

Graphite Lubrication

There is no substance known so smooth or so enduring as **Dixon's Pure Flake Graphite.** It is the best solid natural lubricant ever discovered. It is not affected by heat or cold, acids or alkalies. It is absolutely indispensable to every marine, stationary or locomotive engineer.

Largely increases the lubricating value of all oils or greases.

Will cool bearings and stop "groaning" or squeaking when all other lubricants fail.

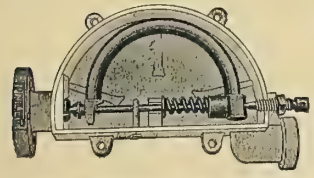
It will pay you to send for Sample and Pamphlet. No charge.

JOSEPH DIXON CRUCIBLE CO., Jersey City, N.J.

Money to Burn?

Well, don't burn it that way, at least. Put on the "Heintz" Steam Trap wherever you have a pipe carrying steam from dryers, heaters, boilers, etc. It saves all waste steam. Even the smallest trap will discharge one gallon of hot water a minute. Operates on difference of one degree of temperature (211° to 212°), and is the only perfect trap made; the only one imitated. Its perfect action depends on a "tube spring" filled with a secret preparation, and the expansion of this spring makes the trap automatic, simple, long lived, perfect —20% to 30% of coal bills saved.

Inquiry will bring more information and some proofs. Ask for Booklet "G"



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BUSINESS NOTES.

KEEL BLOCKS.—Attention is called to the new type of keel blocks illustrated in the advertisement of the Hegley Keel Block Co., 45 Fourteenth street, Hoboken, N. J.

SURFACE CONDENSERS.—Corrugated tube surface condensers from 10 sq. ft. to 2,000 sq. ft. of surface, as well as other devices of value for marine work are offered by the Taunton Locomotive Mfg. Co., Taunton, Mass. An interesting catalogue descriptive of these articles can be had upon application.

FORGINGS FOR TORPEDO BOAT DAVIS.—The torpedo boat Davis constructed by the Wolff & Zwicker Iron Works, Portland, Ore., is fitted with shafting furnished by the Bethlehem Iron Co., South Bethlehem, Pa. A large percentage of the steel forgings furnished for torpedo boats come from the works of the Bethlehem Company.

NEW MARINE RAILWAYS.—There has recently been quite a spread in rebuilding old and establishing new marine railways in Nova Scotia and New Brunswick, and H. I. Crandall & Son, 100 Border St., East Boston, Mass., have been very busy doing much of the work. The Messrs. Crandall make a specialty of marine ways, and have built many of the leading ones in this country.

ANTI-FRICTION METAL.—A new metal called the Perfect Lubricating Metal is being put on the market by the Perfect Lubricating Metal Co., Cincinnati, Ohio. The special claims are that one of its component parts is graphite, that it is considerably lighter in weight than many other anti-friction metals, and that it is a phosphorized tin. Engineers interested should send to the company for circulars and further detail.

ALUMINUM STEEL TUBING.—Something new in the tubing line is being put on the market by the Ellwood-Ivins Tube Co., 487 Broadway, New York. It is a special alloy of aluminum made into very thin seamless tubes which are drawn over steel tubing. The result is said to be tubing which has the strength and elasticity of steel with the attendant advantages of solid aluminum tubing. Full information regarding this tubing can be had upon application to the company.

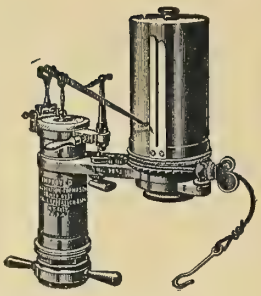
THE BLOOMSBURG SPECIALTIES.—The many orders which have been placed during the past year for steam vessels have brought a large increase of trade to H. Bloomsburg & Co., Newport News, Va., who have sold more steam jets and circulators than at any time during the history of the company. These specialties can be seen in operation in almost any harbor or port in the United States, and people interested in them should send to the company for names of vessels on which they are used in order to make a personal investigation.

A FLOURISHING INDUSTRY.—The Chester (Pa.) Times, of December 16, says: "This city has an industry that is not making any noise, yet which will at no distant day be one of the most important in this city. It is the manufacture of the Baldt anchor. The anchors are made at the Penn Steel Works and though they have not been long on the market, they are in use by vessels that ply on many of the important rivers and harbors of the Atlantic coast, on steamers on the great lakes and upon ocean steamships. They have been approved by United States naval officers and seamen on all kinds of craft. The Baldt anchor is a distinct departure from the old style fluke and is a simple, but most ingenious device.

PENBERTHY INJECTORS.—Attention is called to the exceptionally fine advertising which has been done in these pages lately by the Penberthy Injector Co., Detroit, Mich., and especially to the new cut which appears in this month's issue. This company is believed to be the largest injector manufacturing company in the country if not in the world and, of course, gives every attention possible toward covering its field in the most thorough way.

HOLLOW STAY BOLTS FOR BOILERS.—Hollow stay bolts are coming into extensive use in boiler making and we are informed that the Falls Hollow Stay Bolt Co., Cuyahoga Falls, Ohio, made a recent shipment of a car load of these bolts to one of the large marine boiler manufacturers. These bolts are offered as a safe guard against failure and have unusual lasting qualities, being rolled hollow. Full information regarding these bolts can be had from the manufacturers.

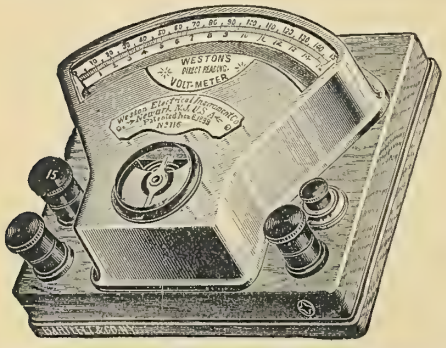
YOU WILL NEVER reach top notch until you OWN AN INDICATOR and know how to use it. We are offering special low prices for orders, NOW.



(IMPROVED ROBERTSON-THOMPSON.)

NO FLEXIBLE PACKING has such a record as EUREKA, and if you have not tried it you have missed a GOOD THING; 2 labels cut from front of boxes secure a handsome pack of playing cards. TRY EUREKA. FULTON FLEXIBLE METALLIC PACKING fills a long-felt want. Can be carried in closet same as EUREKA. Send for Sample.

JAS. L. ROBERTSON & SON, 218 Fulton Street, N. Y.



Weston Standard Portable Direct Reading Voltmeter.

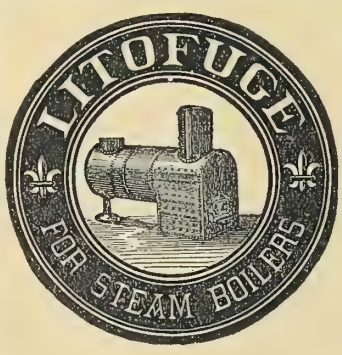
WESTON STANDARD PORTABLE

DIRECT READING

VOLTMETERS, AMMETERS, MILLIVOLTMETERS, VOLTAMMETERS, MILLIAMMETERS, OHMMETERS, PORTABLE GALVANOMETERS, GROUND DETECTORS AND CIRCUIT TESTERS.

Our Portable Intruments are recognized as THE STANDARD the world over. Our VOLTMETERS and AMMETERS are unsurpassed in point of extreme accuracy and lowest consumption of energy.

WESTON ELECTRICAL INSTRUMENT CO.,
114-120 William St., NEWARK, N. J., U. S. A



Free to Engineers.

Upon receipt of name and address and where employed, a fine English bulldog

BRIAR WOOD PIPE.

There's nothing like LITOFUGE for Marine Boilers.

It won't cost you a cent to try LITOFUGE unless it does just what we say it will do. We claim—

That it will clean the dirtiest boiler in 60 to 90 days, without injuring the metals;

That it is the *only* Compound that will *positively* prevent the formation of scale in a new or clean boiler;

That it will prevent corrosion, and stop it where it has already started

That it does not eat the scale; simply loosens it from the metals.

LITOFUGE acts mechanically (not chemically), contains no soda, soda ash, nor acid. Give us nominal horse power of your boilers and character of water used, and we will send you, freight prepaid, a trial order, to be paid for *only* if satisfactory. Pamphlet for the asking.

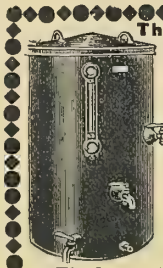
LITOFUGE MFG. CO.,
1710-1712 Market Street, PHILADELPHIA, PA.

PATENTS SECURED.

Inventors desiring to secure full information in regard to the necessary course to pursue to obtain a patent, should send for our booklet on the subject.

MAILED FREE TO ANY ADDRESS.

PATENT DEPARTMENT:
THE POWER PUBLISHING CO.,
WORLD BUILDING, NEW YORK.



The CROSS OIL FILTER

actually reduces oil bills 50% or more. Sent on approval. Used in 17 countries. Adapted to steam vessels of every description. Send for circulars, testimonials, etc.

THE BURT MANUFACTURING CO.
AKRON, OHIO, U. S. A.
The Largest Manufacturers of Oil Filters in the World.

COMPLETE LIGHTING PLANT.—The coast survey steamer Blake, which has been hauled out at Baltimore, is having a complete electric lighting plant installed by The E. G. Bernard Co., Troy, N. Y.

ENGINEERS' SPECIALTIES.—A line of several specialties of particular interest to engineers is illustrated in a little folder issued by the American Steam Gauge Co., 36 Chardon street, Boston, Mass. They include the American Thompson Improved Indicator, the American Patent Pop Safety Valve, pressure and vacuum gauges, underwriter water and cylinder relief valves and planimeters.

LIFE PRESERVERS.—The recent storm along the Atlantic coast and the unusual gales on the lakes have led to a great demand for life preservers, causing the Armstrong Cork Co., Pittsburg, Pa., to be pretty nearly swamped with orders for the best class of life preservers.

VALVES.—A new line of blow off and operating valves has been put on the market by the Homestead Valve Mfg. Co., Homestead, Pa. There are several features regarding these valves which are well worth investigating. A catalogue of the company explains these in some detail.

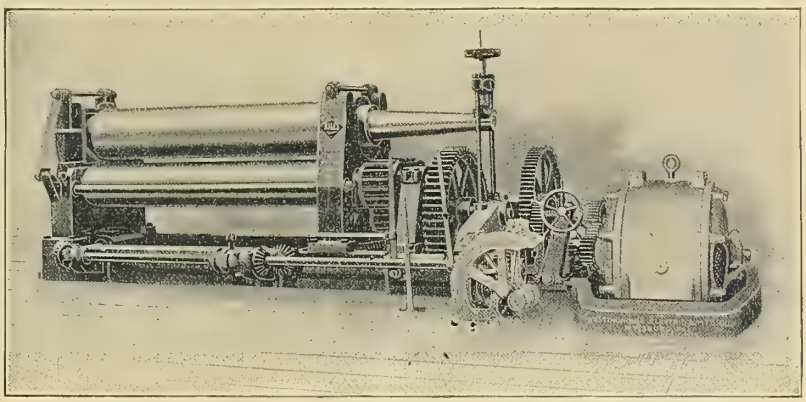
BEARING METAL.—Engineers and others having trouble with bearings will be interested in the nickel babbit and X L C R babbitt advertised elsewhere by J. J. Ryan & Co., 68-74 West Monroe street, Chicago. This company makes a specialty of making bearings suited to special conditions.

LARGE DREDGING CONTRACT.—The New York Dredging Co., World Building, New York, has begun work on an extensive contract for dredging the Christiana river, Wilmington, Del. The immense hydraulic dredges will fill in adjoining marshes and reclaim a large area of property.

WESTINGHOUSE

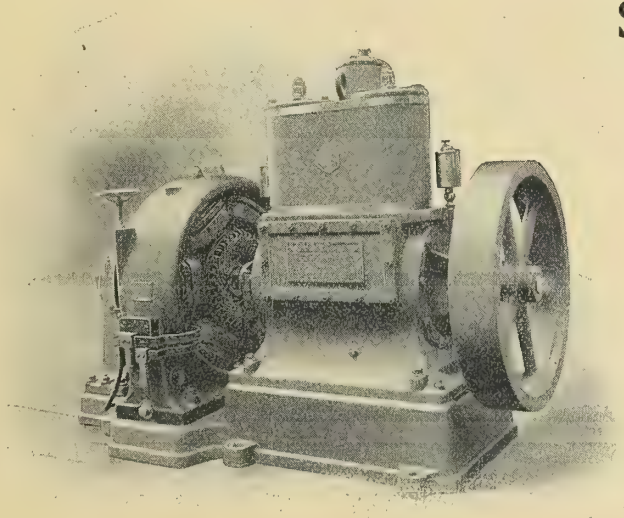
ELECTRIC POWER

as applied to mills and shipyards by the "Westinghouse System," reduces the operating expenses to the minimum, increases the output and introduces many advantages that are impossible with other systems.



40 H.P. Type "C" Motor, Driving Heavy Plate Bending Rolls.

WESTINGHOUSE ELECTRIC & MFG. CO., Pittsburg, Pa.,
And all Principal Cities in the U. S.
WESTINGHOUSE ELECTRIC CO., Ltd., 32 Victoria Street, London.



SHIP LIGHTING.

The Westinghouse engine is peculiarly adapted to marine service by reason of the small floor space required and the reliability which may be placed upon the engine for long and uninterrupted service.

WESTINGHOUSE MACHINE CO.,
Manufacturers.

WESTINGHOUSE, CHURCH, KERR & CO.,
Engineers.

New York. Boston. Chicago.
Pittsburg. Detroit. Philadelphia.

The name of WESTINGHOUSE is a guarantee.

SPECIAL NOTICES.

Announcements under this heading will be inserted at the uniform rate of thirty-three-and-a-third cents a line. Lines average ten words each.

BOATS BUILT CHEAP.

Boat Builder on Inland Lake is satisfied with day wages during Winter. Launch, cat, or small sloop hulls contracted for now can be figured low. Address BOATBUILDER,
Care of MARINE ENGINEERING,
World Building, New York.

NEW YORK'S FINEST PLEASURE TRIP.

The finest pleasure trip out of New York harbor is by the boats which ply between New York and Hartford, Conn.

The screw steamers "Middletown" and "Hartford" are new and commodious, the meals served excellent, the trip inexpensive, and the scenery up the Connecticut River superb.

The New York Pier is 24 East River, and the boats leave each end daily at 5 P.M., except Sundays

Calendars for 1899 Received.

From the Boston Belting Co., 256 Devonshire street, Boston, Mass., a small celluloid pocket calendar, 2 by 3 1-2 in. in size.

Also from the same company a very neatly bound calendar in book form with 16 pages, the size being 1 1-2 by 2 in. Besides the calendar this book contains oiled paper divisions for carrying postage stamps, information regarding many matters, postage rates and other data.

From the Youngstown Iron & Steel Roofing Co., Youngstown, O., a calendar 13 by 20 in. in size, containing a reproduction of the famous picture "The Bride," by Bisson.

Copies of these calendars can be had up to the limit of the supply by writing to the companies and mentioning Marine Engineering.

BOUND VOLUMES

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MARINE.... ENGINEERING

For 1898

Now Ready for Delivery.

Price by Mail $3.50.

The Marine Publishing Co.,

WORLD BUILDING, NEW YORK.

MAY, 1897 ⚜ Who has a copy of Marine Engineering of this date for sale?

Marine Engineering, World Building, New York.

DO YOUR OWN GALVANIZING.

"Revolution in Galvanizing"

The multitude of articles that can be galvanized by our new "COLD PROCESS" is without any limit. The thousand of things heretofore ungalvanizable, for instance, tempered tools and instruments of every description, screws, nuts, springs, locks, etc, can be galvanized in a superior manner.

Uniformly smooth surface preserved. Thickness of coating regulated. Saving of spelter 80 per cent. Many other advantages. Two years practical use with results absolutely satisfactory. Territory and shop right for sale. Number of plants running, to which we can refer. Galvanizing done at our New York plant, 9-11 Franklin street.

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346 Broadway, NEW YORK.